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The combat system design and test criteria for Iguana(tm) armored vehicles

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THESIS

THE COMBAT SYSTEM DESIGN AND TEST CRITERIA FOR IGUANA™ ARMORED VEHICLES

by

Irfan H. Alper

June 1999

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Robert C. Harney

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Ground vehicle mobility advances for the future combat vehicles fleet will be achieved through smaller and lighter systems with improved weapon stabilization, improved ride and agility, and reduced acoustic/IR signatures. The Iguana™, a tracked vehicle concept based on a recently patented suspension and track design, could deploy to hot spots world-wide on peacekeeping and combat missions which require extra flexibility to adapt to diverse terrain, weather and threat conditions. A sophisticated sensor suite integrated with weapon systems will guarantee battlefield dominance and vehicle survivability can be enhanced with revolutionary composite armor. Hybrid electric drive will mainly enhance survivability, fuel economy, stealth, operational capability and acceleration performance. Power electronics developments will speed up the transformation from conventional gas engines to hybrid armored vehicle drive systems. This thesis presents a combat system integration process for an Iguana™ based armored vehicle. It lays out steps to be taken in conceiving and developing the armored vehicle starting from the Mission Need Statement. Scenarios are used to create a context within which to define realistic operational requirements. Functional flow modeling for the interoperable reconnaissance, forward observer and anti-guerrilla version armored vehicles provides the analytical basis for defining subsystem characteristics. A particularly important operational need is for night vision sensors. The U.S. Army Night Vision & Electronic Sensors Directorate's FLIR92 and ACQUIRE computer programs are used to establish feasible Iguana™ thermal night vision device performance requirements.

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THE COMBAT SYSTEM DESIGN AND TEST CRITERIA FOR IGUANA^{TM} ARMORED VEHICLES

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Ground vehicle mobility advances for the future combat vehicles fleet will be achieved through smaller and lighter systems with improved weapon stabilization, improved ride and agility, and reduced acoustic/IR signatures. The Iguana™, a tracked vehicle concept based on a recently patented suspension and track design, could deploy to hot spots world-wide on peacekeeping and combat missions which require extra flexibility to adapt to diverse terrain, weather and threat conditions. A sophisticated sensor suite integrated with weapon systems will guarantee battlefield dominance and vehicle survivability can be enhanced with revolutionary composite armor. Hybrid electric drive will mainly enhance survivability, fuel economy, stealth, operational capability and acceleration performance. Power electronics developments will speed up the transformation from conventional gas engines to hybrid armored vehicle drive systems. This thesis presents a combat system integration process for an Iguana™ based armored vehicle. It lays out steps to be taken in conceiving and developing the armored vehicle starting from the Mission Need Statement. Scenarios are used to create a context within which to define realistic operational requirements. Functional flow modeling for the interoperable reconnaissance, forward observer and anti-guerrilla version armored vehicles provides the analytical basis for defining subsystem characteristics. A particularly important operational need is for night vision sensors. The U.S. Army Night Vision & Electronic Sensors Directorate's FLIR92 and ACQUIRE computer programs are used to establish feasible Iguana™ thermal night vision device performance requirements.

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I. INTRODUCTION

A. BACKGROUND

This thesis includes a combat system design study for Iguana™ armored vehicle family. The Iguana™ concept, which was invented and patented (United States Patent number: 5,318,141, June 7, 1994) by David W. Hansen, was reduced to practice in a 7,500 pound tracked vehicle with a maximum payload weight of 2,000 pounds. The National Automotive Center of U.S. Army's Tank and Automotive Command in cooperation with the Naval Research Laboratory contracted in April 1996 to have a Model 0 Iguana™ (Figure 1) constructed. Model 0 was first demonstrated in October 1996. It was designed to use readily available components and was operational within 5 months of start of construction. Among the features demonstrated were the abilities to:

- Carry a payload of at least 2,000 pounds
- Climb over obstacles up to 1.8 m in height
- Operate on paved highways without damage to the road or The Iguana™'s tracks
- Operate in mixed snow, rain and mud conditions without destroying the road
- Climb or otherwise traverse embankments or hillsides of up to 45 degrees slope
- Traverse across a 30 degree slope without losing tracks
- Demonstrate ability to self-load and unload onto a truck bed at least 1 meter high
- Operate as an amphibian

- Operate in sand, mud, river banks, foliage and other environments where wheeled vehicles would become stuck
- Perform all of the above without modification to the basic vehicle, e.g., amphibious operation does not require "buttoning up"

Figure 1. The prototype Model 0 Iguana™

The Iguana™ represents a major advance in the design of the suspension system for tracked vehicles. It achieves its performance through the use of a combination of features in the track tensioning system and the design of the tracks themselves. Consequently, the Iguana doesn't suffer from the limitation found in most other tracked vehicles with respect to cross-hill mobility. Most tracked vehicles can only traverse hills with no more that 20-30% grade otherwise they slide out of their tracks. The Iguana

Model 0 has been demonstrated to hold its track while traversing hillsides of 60% grade. The Iguana™ armored vehicle family described in this thesis makes use of other new technologies such as composite armor and hybrid electric drive to overcome deficiencies found in current armored vehicles. We also introduce a higher level of combat system and vehicle integration than is currently achieved in most armored vehicles.

The combat system design of a new combatant, such as an armored vehicle, fighter plane or arsenal ship, always requires a breadth and depth of engineering knowledge to create a world-class-integrated warfare system. Before solving the problem, the definition and boundaries of the problem must be set up. A Mission Needs Statement (MNS), as used in the U.S. Department of Defense acquisition system procedures for creating new capabilities, is the first step in understanding why we need a new combatant vehicle as opposed to making modifications to current systems (potential material alternatives) or changes in doctrine, tactics, training and organization changes (non-material alternatives). Financial, political and other possible constraints must also be explored and made explicit in the mission definition phase. The Mission Needs Statement generally states the basic operational capability for the combatant and provides rough information about the mission and threat environment.

The Operational Requirements Document (ORD) is contract between the operational community and the design community. It guides the system engineers and designers in their creation of a system that meets the desired performance criteria. The ORD evolves from the MNS through much analysis of the threat, natural environment, missions, cost, producibility, availability of technology, and other factors that influence the creation of a new combatant. This analysis is done well only when all parties to the

"ORD contract" participate in its creation. Thus a complex system requirement, as expressed in a successful ORD, will have considered the limitations of physics and the operational desirability of various features of the required system. Most of the requirements analyses make use of scenarios that visualize realistic combat conditions. Functional flows detailed in chapter III also elaborate on the nature of the requirements listed in the ORD and provide a record for the rationale for the different versions of Iguana™s. Each version is able to perform a subset of the missions of the Iguana™ family. From each of these partial missions, subordinate duties are extracted and these are then further decomposed into the actual tasks that specific components will be designed to perform. For example, tasks or functions can be allocated to the building blocks of systems, namely hardware, computer programs and people. Assemblages of these building blocks in the detection subsystem of the Iguana™ reconnaissance version might envision an infrared detector, a signal processor with averaging done by computer codes and an operator that detects and interprets the image as being a particular kind of tank. It is not surprising that there are generally many design solutions to each task rather than a unique recipe. After constructing a detailed spreadsheet of duties/tasks and design solution alternatives, the system engineering process is called upon to do trade-offs since seldom is there an obvious optimality problem to solve. However, whenever possible the creation of optimality criteria permits the application of optimization techniques widely applied by the practitioners of operations research. Simulations and performance tests in virtual battlefield environments are becoming available and significantly facilitate the system analyses for the engineering and manufacturing development processes. Life cycle operational support, modular design for future modifications, interoperability with

other force units, integration into the digitized battlefield, timelines for system synthesis and disposal plans are also involved in an Iguana™ master plan which guides the development.

B. PRINCIPLE CONTRIBUTIONS

This thesis serves as a first development step in the design of an innovative armored vehicle combat system. It defines the missions that Iguana™ is to handle in a future dynamic threat environment facing a new global armored force deployment in a stipulated set of operational conditions. The Iguana™ Mission Needs Statement emphasizes the deficiencies of current systems and calls for alternative solution approaches, recognizes specific development constraints, outlines expected tactical usage of the Iguana™, and roughly describes the required main subsystem characteristics. The Operational Requirements Document is synthesized from analyses of tactical needs and the technically possible capabilities. Both of these documents were generated by the author after conducting the required analyses and having numerous discussions with his advisors. The detailed information on subsystems was obtained from technical and tactical defense periodicals and companies, such as PEI Electronics Inc. for hybrid electric drives, ATAK Inc. for composite armor, and Unique Mobility Inc. for power electronics. The Iguana™ thermal imaging device parameters were developed through analysis to answer the Operational Requirements Document demands by using U.S. Army Night Vision & Electronic Sensors Directorate's FLIR92 and ACQUIRE thermal imaging device performance test computer programs. U.S. Army Training and Doctrine Command (TRADOC) and Tank Automotive Research, Development and Engineering Center (TARDEC) projections for future armored vehicles are also mentioned in this thesis.

C. THESIS OUTLINE

Chapters II-V of this thesis focus on the Iguana™ mission and operation analyses while the following chapters VI-X explain some required Iguana™ combat system features in detail. This thesis begins with the author's Mission Needs Statement for an Iguana™ armored vehicle family. Scenarios and functional flows are developed to aid in the visualization of expected operations in various threat environments. From these visualizations, the role played by the Iguana™ combatant is derived and the implied requirements for the system are recorded. Next, the Operational Requirements Document describes the specific subsystem characteristics that fulfill the missions consistent with the requirements derived from the scenarios and functional flow analyses. Note in the Defense Department Directives (DOD 5000 series) for the development of new systems that an acceptance test plan is a recognized, useful way, and effective way to clarify what is being required of a new system. The subsystem's analyses and test plans on the armor, drive system, power electronics and thermal imaging device provide enough information for a detailed comparison among the alternative solution concepts. For example, FLIR92 and ACQUIRE programs significantly refine and balance the thermal imaging device components to avoid unbalanced performance demands on individual parts while yielding satisfactory system level performance. The examined composite armor technology, if applied, provides numerous tactical and survival advantages for its future operations of armored vehicles. Power electronics is evolving so rapidly that the hybrid electric drive has become feasible for incorporation in armored vehicles today.

II. IGUANA^{TM} ARMORED VEHICLE FAMILY MISSION NEEDS STATEMENT

Terrain and weather conditions directly affect situational awareness and mobility performance in combat missions. Rugged, muddy, snow-covered, and sandy ground conditions have negative effects on the mobility of wheeled or tracked vehicles. Rivers, artificial obstacles, steep ramps, swamps, minefields, water canals also restrict the avenues for advance. Fog, rain, snow, drizzle, dust, long distance and other day/night vision handicaps aggravate the detection capabilities of the electronic sensors, sights, and eyes. A fighting vehicle that overcomes these terrain and weather obstacles is crucial for modern battlefield operations.

Today, reconnaissance, anti-guerrilla, rapid deployment, border security, UN peacekeeping, forward observer missions are commonly executed in these diverse terrain and weather conditions. Threatening innovative lethal technologies press to the fore the combatant survival concerns whether in conventional or irregular warfare environments. Stealthy vehicle configurations that combine low IR and acoustic signatures, minimum radar cross section, and camouflage are now as important as effective armor ever was. Threat warning systems and active countermeasures should also make contributions to battlefield survivability.

The irreversible trend of battlefield digitalization, i. e., the introduction of digital networks tying all elements of a force together, will revolutionize command and control of armies, place great demands on wireless communication systems, and place further pressure for timely and accurate information from intelligence processes. Electronic warfare and countermeasures will follow a parallel improvement. Cutting edge information technology applied to information warfare will lead us to the tactical Internet

as a critical combat element in the very near future. Navigation, fire control system, optoelectronics, secure data, image, and voice transfer systems already depend on digital technology.

Strategic mobility considerations increasingly demand rapid force deployment. The operational capabilities of vehicles must suffice on different terrain and in varied weather conditions as well as against various hostile threats. So the combatant must have the ability to deploy/respond quickly and operate with sufficient tactical flexibility, whenever and wherever required, to enable wide range operations. Self-contained sustainability without access to support and maintenance facilities during periods of extended deployed operations enable the desired ability to operate independently.

The basic vehicle configuration must have the flexibility to adapt to changes in the threats, missions, and technologies. It must be an affordable solution, that is, it must be at a cost which is in balance with competing budgetary demands. The design, conceived as an independently operational combatant, also provides great flexibility in the force structure in the face of changing tactical needs.

When we scrutinize the operational features of this kind of combatant, it can be easily discerned that this vehicle includes many familiar characteristics of the envisioned future scout, forward observer and anti-guerrilla fighting vehicles. The standardization of the vehicle has the potential to reduce the research and development (R&D), procurement, maintenance, and training costs. while increasing interoperability. These different versions of the Iguana™ vehicles should be easily obtained by changing some vehicular parameters and subsystems on the same chassis.

The adaptation of new tactics and organization structures to the characteristics of the new combatant will help to meet some of the operational needs. The formation of rapid deployment forces and an increase in the number of the anti-guerrilla units using these combatants are examples of organizational options to be considered. The creation of new tactics is a dynamic process that reflects the interplay of new threats, changing missions, and new operational settings. The design of a new combatant with a new set of capabilities and changed performance can enhance the integrity of operational solutions and lead to the new tactics and further structural changes.

Current combatants do not solve operational problems described above for the following reasons:

1. Lack of Integration of vehicle and combat system: Even if some alternative vehicles show partial success on these missions, the need for an integrated operational war fighting system is inevitable. The use of existing vehicles creates many coordination problems with a consequent increase in reaction time. For instance, the transportation and power requirements of ground radars limit it to usage as an independent system. In contrast, if the reconnaissance vehicles were equipped with precise weapons and had integrated detection equipment, they could perform efficiently find-and-destroy missions.

2. Limited Mobility: The playground of irregular forces is frequently on rough, swampy, jungle or desert types of terrain. The common features of these environments are they obstruct or slow forward motion of wheeled vehicles and degrade tracked vehicle mobility. Swamps, rivers, and small lakes generate a need for amphibious capabilities. Sometimes tanks can also have mobility failures on steep ramps or on muddy, frozen and rocky terrain. This set of circumstances with existing vehicles begs

for reducing the pressure on the ground, increasing the efficiency in terms of power to weight and power to volume ratios all the while seeking additional endurance or reduced fuel consumption per mission.

3. Inadequate Performance and Integration of Combat System Components: Future armored vehicles must possess superior target acquisition capabilities which exploit information/intelligence awareness, and advanced fire control, while anticipating the need to do these missions with a reduction in manpower. Technology exists to accomplish this, such as, spoken human-machine dialogue/commands to accelerate information flow and the target acquisition process. Future armored vehicles must have a combat system which enables engagements while either moving or stationary, this includes detecting and identifying threat forces at extended ranges and proceeding through fire control to engagement and damage assessment. Targets include personnel, bunkers, light and heavily armored vehicles, and rotary and fixed wing aircraft. Targets must be rapidly detected, recognized by type, and identified as friend or foe without the target knowledge, at ranges beyond the threat's ability to counter-detect own combatant. Countermeasures or environmental conditions (such as weather, day/night, or the most cluttered battlefield) must not disable these capabilities. Specialized reconnaissance units will require higher resolution target acquisition to support the extended ranges encountered in their operations. Sensor suites at every level will be critical to the target acquisition process and must provide real time information to commanders for immediate decisions on a fluid battlefield using available communication systems. Sensors must have the capability to allow for the use of remotely operated weapon systems with sufficient resolution and low false alarm rates for both detection and identification.

Enhanced target acquisition is critical to the force's ability to positively detect, track, engage, and kill targets despite the most cluttered battlefield or sophisticated camouflage systems.

4. Border Control Inadequacies of Current Combat Systems: Infiltration is a serious problem on the Israeli-Lebanon and Turkish-Iraqi borders. The border outposts are susceptible to surprise guerrilla raids from the surrounding rough terrain that prevents effective hot-pursuit operations. The increasing number of casualties proves the need for better systems to cope with these guerrilla raids and infiltration. The drug smugglers and refugee movements across the US-Mexican border demonstrate a new dimension on the border control problem. UN peacekeeping operations such as in Bosnia and Cyprus require mobile observation teams to detect violations, classify them as to type and determine responsibility all in a timely way.

5. Impacts of Mines on Mobility: Improving mine technology poses a serious threat to current fighting vehicles. Mines limit mobility, create nuisances and delays for the advancing units and inflict casualties without close engagement with the enemy forces. Thus, there is an urgent need for active and passive counter measures against the mine threat. One possible countermeasure is to increase the amount of terrain that can be traversed by the combat vehicles. This forces the mining forces to distribute larger quantities of mines in increasingly hostile physical settings.

6. The Combatant Signature Vulnerability: The opponents' warning systems exploit our current combatant's IR signature, acoustic signature and radar cross section of which exposes an acute vulnerability that reduces combatant survivability. The immediate effect of this to reexamine the source of these signatures and determine if

means exist to combatants detectability. Basic power requirements must revised to meet new agility standards and payload demands while reducing vulnerabilities. Similarly armor protection specifications must be reconsidered and traded-off against active protection measures due to new threats such as smart top attack weapons, and the need for reduced radar cross section.

7. New Deep Attack Missions: The modern battle line shows a distinct nonlinear character. Extensive tactical deep attacks or scout missions will be executed in the enemy rear regions. These kinds of operations need an agile and long-range vehicle for operations in widely diverse terrain. Superior battlefield surveillance capacity in the attack forces will increase the efficiency of the tactical deep attacks thus making them a preferred mode of operation.

8. In low intensity anti-guerrilla operations Iguana™ is employed in the area domination, border patrol, route protection, convoy escort, hot pursuit, and show-of-force exercises without the terrain limitations.

9. The user-friendly design of new combatant will facilitate crew training and increase their actual operational performance. It also will minimize the crew size without impairing the performance of assigned functions.

10. Future armored vehicles must possess overmatching lethality against all projected threat systems. This includes improved probabilities of hitting and killing heavily protected systems while either stationary, moving, or maneuvering, in all environments (to include natural and man-made obscurants, clutter, darkness, and poor weather), at extended ranges. The capability to automatically detect, identify, track, and assess damage against targets will improve combat system lethality. The new combatant

must be able to defeat emerging threat protective systems that may include advanced reactive and/or passive armors, signature management, electronic countermeasures, or active protection systems. Inherent within this capability requirement is the need to destroy targets within and beyond firing vehicle line of sight, directed by cueing from on-board or off-board sources. Similarly, systems must have the capability to designate targets for servicing by other firing combatants. Also, combat system lethality must be more efficient in terms of reduced ammunition requirements (fewer rounds required per kill) and reduced crew interaction requirements (workload).

11. Despite the availability of all-seeing long-range battlefield sensors that are mounted in unmanned air vehicles (UAVs), helicopters, or aerial platforms; ground scouting is still necessary for mounting continuous operations. Ground scouts can operate in all weather conditions; are unaffected by air defenses; can exercise on-site human judgment; can directly retrieve objects; and can complement airborne sensors by operating in areas obscured from aerial observation by terrain, foliage, or camouflage. [Ref. 1]

12. For most major armies, the focus of force development in the coming decade is the attainment of information dominance through implementation of information operations and exploitation of information technology. Reconnaissance vehicles, furnished with human-intelligence sources, will still play a critical role in the establishment of information dominance on the heavily digitized battlefield. [Ref. 1]

III. SCENARIOS

A. HEZBOLLAH AND ISRAELI SECURITY ZONE - SOUTH LEBANON

From a military standpoint, the terrain in South Lebanon seems totally unsuited for armored warfare. It favors the defender, with its rugged, hilly countryside. Rock-covered basalt hills with steep ravines make cross-country movement, even with tanks, extremely difficult, and in most cases armored vehicles are road- or track-bound. As the ridges normally run from east to west, movement is geared through the wadis, between the ridges. These are passable only in part and, with their steep canyon-like walls, make formidable obstacles. Most of the region is pocked with thick shrubs, providing excellent hiding places for tank-hunter teams and ambushes that are very difficult to detect before they are executed. Furthermore, the area is filled with hundreds of small villages, mostly situated on the high ground, from which guerrilla fighters can mount their surprise attacks and swiftly return to good hiding places amongst the mostly friendly Shiite population.

The Israelis in the so-called Security Zone in South Lebanon have implemented a series of strongpoints located widely apart and not always capable of rendering mutual fire support. One of the most difficult tasks is to maintain lines of communications to and from those strongpoints and the supply depots on the Israeli border. As most of the roads are winding narrow tracks, they provide the attackers with easy access to ambush sites, where they emplace explosive charges and mount rocket attacks on the Israeli Defense Forces (IDF) traffic. Most of the costly IDF losses have been caused by such ambushes, and considerable effort is necessary in order to maintain open supply routes to the strongpoints. [Ref. 2]

Time: 16 30 (local) – July 13, 1999

After Middle East Peace Process negotiations lost their momentum and Israel insisted on retaining the security zone in South Lebanon, Iran and Syria increased their support to Hezbollah by supplying TOW, Sagger and Spigot guided anti-tank missiles. Because of heavy casualties on marching patrols and lightly armored wheeled vehicles inflicted by remotely controlled road-side explosive charges and rocket attacks, the supply convoys and patrol missions between strongpoints were modified so they are now executed with the support of armored vehicles like tanks, armored personnel carriers (APCs), and Iguana™ armored vehicles. Losing two Merkava tanks due to the anti-tank guided missile (ATGM) team ambushes in the last years is an indication of the increasing Hezbollah capacity in addition to Sagger and AT-4 Spigot ATGM's.

In a seemingly routine patrol mission in South Lebanon with forces consisting of two Merkavas, two Iguana™ armored combatants, and one infantry platoon with APCs, everything looks like normal until the leading tank shudders with the explosion of anti-tank mine. The second tank commander, who is also patrol commander, notices that there is only damage on the other tank's one track in spite of the great impact. While he orders the other vehicles to occupy suitable positions to search for other nasty surprises, he evaluates the terrain and tactical situation. Finally he begins to report the incident and he asks for a recovery vehicle for the immobilized tank and aerial reconnaissance of the area for guerrilla activities. During this standard procedure, one of the Iguana™ combatant commanders suddenly gives an anti-tank missile launch warning on the radio net. The patrol commander pops up his head from the hatch to understand the situation while he orders his driver to execute rapid evasive maneuvers. The crippled tank and

Iguana™ combatant that spotted the missile launch site open fire and launch smoke mortar rounds in the direction of the missile launcher, hoping to disturb the guerrilla gunner's concentration during the critical navigation phase, or obscure his vision by smoke. The impact of the missile is neutralized by reactive armor but the patrol commander on the hatch is not as lucky as his tank. As the infantry platoon commander takes over the command, the first impacts of mortar rounds herald that they are under an organized attack. One of the Iguana™s passes the information about suspected movements on a nearby hill covered with thick shrubs before the start of heavy rocket and machine gun fire. They are probably the covering element of the ATGM team. The infantry platoon commander decides to attack the hill with support of tank fires by leaving mortar fire impact area while two Iguana™s head for missile launch site on the rough terrain. Iguana™s detect and destroy the ATGM team that tries to reposition for the crippled tank. One of the Iguana™s is able to locate the mortar position with its sensors and pass this data to the supporting artillery unit. The Iguana™ gives necessary corrections on the radio after observing the first artillery round impacts. The sound of approaching attack helicopters finally means the start of the pursuit operation.

B. PKK AND TURKISH-IRAQI BORDER - CUKURCA

The Turkish-Iraqi borderline has a generally mountainous character. The terrain is rugged and traffic is strictly road-bound. Steep rocked hills, ravines, and small forests along the valleys are common. Severe and erratic climate conditions also are the main operational handicaps especially in winter (snow storms, avalanches, heavy showers). After the Gulf War, the Northern Iraqi Security Zone was created by allied forces in order to protect local population, but continuous skirmishes between rival Kurdish groups

turned the area into an authority vacuum. PKK guerrilla organization made use of these suitable conditions by launching attacks against Turkish security forces from this area. This region is also used for guerrilla logistic and training centers. The infiltration of guerrilla groups to the inner parts of country from this area is always an anxiety for Turkish commanders.

Time: 22 30 (local) - October 28, 1999

According to intelligence reports and unmanned air vehicle (UAV) reconnaissance, a group of guerrilla has approached the Turkish-Iraqi border and is waiting for a convenient infiltration time to cross the border. The possibility that the infiltrators are carrying surface to air missiles (SAMs) missiles increases the importance of inactivating this group. Erratic weather conditions worsen the possibility of detecting this group. Five or six known trespassing sites are set up for ambush by mobile infantry units with the support of Iguana™s. Several distracting assaults or mortar nuisance fire are expected from the infiltrators to disguise the main infiltration body.

The Iguana™ sensor operator briefly detects some signatures at 4 km but because the terrain is hilly he doesn't have a long exposure opportunity. He passes this intelligence to the other ambush elements and to the tactical operation center simultaneously. One Iguana™ is ordered to change position under the cover of noise from the rain and thunder. In this new position, it can easily view the approaching routes, which are normally out of sight. After 20 minutes, the repositioned Iguana™'s sensors detect and locate the approaching column at 3 km. Some of the ambush teams are channelized to new positions to block the advance of the approaching column. The tactical operations center asks several Iguanas to check the security of certain deep

landing zones in Northern Iraq with their long-range sensors. Air assault troops, who will encircle the guerrilla group when the engagement starts, are going to be dropped in these zones. One Iguana™ passes an alerting message that there is a herd of wild animals at a location nearby the ambush teams (who need to avoid making a mistake of thinking it is the infiltrators). An ambushing team is also notified that it is in an incorrect position and needs to reposition. When the forward elements of the guerrilla column finally fall into the ambush, Iguana™s begin to fire at the crowded guerrilla spots with tracer bullets in order to lead the ambush fire onto them. When the air assault operation starts, guerrilla column begin to split up into small groups and try to leave the ambush site. Iguana™s also continue to correct artillery, mortar and attack helicopter fire on the withdrawing guerrilla elements. A friendly team reports that they are engaging with the guerrillas at a very close distance on the rough terrain and have several wounded personnel. Further they report that they can't evacuate them immediately because of heavy fire. Two of the Iguana™s are sent to this spot to relieve pressure on this team and help them to overcome the guerrilla resistance. The usage of other fire support elements is considered to be too risky for the relief of this closely engaged team due to possibilities of fratricide. The systematic effort at the cat-and-mouse game lasts until dawn. At dawn, the operation area is searched carefully by mobile teams while Iguana™s stay alert and scan the operation area from the dominating high ground positions.

C. TURKISH-GREEK WAR - MERIC RIVER, THRACE

At the beginning of September, the Meric River, which constitutes the Turkish-Greek border, reaches its shallowest level. The Greek side of the river near the Aegean Sea is largely a swamp. This area is also fortified with wide water canals parallel to the

river in order to increase the defensive capacity of the terrain. The area is partially covered with small forests and thick shrubs. After rain showers, the muddy characteristic of the ground aggravates the cross-country movement capacity of tracked vehicles. During September, the weather conditions change erratically.

Time: 05 00 (local) – September 11, 1999

The political deterioration between Greece and Turkey leads the Greek government to a limited war with Turkey in order to prevent Turkish European Community membership and expose the Cyprus problem globally. During a Greek-South Cyprus joint exercise, a Turkish reconnaissance aircraft is shot down with a SAM missile over Cyprus. Dogfights over Cyprus rapidly extend to the Aegean Sea. However, the initiation of air strikes and naval engagements indicates that the current situation quickly may be transformed into a general war. While the Turkish Army uses the forward artillery observer version of Iguana™s, the Hellenic Army has Iguana™'s reconnaissance version in its inventory.

The tank battalion forward observers are positioned at the riverbank in order to detect the latest Greek deployments across the river for the oncoming Turkish fording operation near Enez town. They are generally able to locate the front line defensive positions and the supply roads perpendicular to the river by using long range sensors. This intelligence is passed to the tactical operation center of the tank battalion. This will enable the selection of the fording places and the routes of the tank battalion will be chosen to avoid hitting anti-tank minefields and other obstacles. Across the river, the Greek reconnaissance company tries to locate the center of the Turkish tactical deployment and to predict the exact fording sites.

The start of an intense Turkish artillery barrage indicates the beginning of the expected fording operation in the foggy morning. The tank battalion's mission is to secure the bridgehead and to give the combat engineers the opportunity for setting up a pontoon bridge across the Meric River. The tank battalion equipped with snorkels begins to cross the Meric River with Iguana™s throwing back the Greek front-line resistance. Heavy losses are incurred during the fording. The mission of the Greek reconnaissance company is to protect the withdrawal of the front-line elements to the next defensive line and to maintain contact with the advancing Turkish forces in order to provide tactical intelligence about them. Their superiority mobility makes it easy for them to withdraw from the swampy land and the wide water canals. The ability to fire at the oncoming Turkish force during its floating time is another positive factor for them. A Turkish Iguana™ detects low-level attack helicopters approaching and warns the tank companies and stinger teams. The tank commanders and attack helicopter pilots are strictly instructed to check the identification before firing on any Iguana™, because both sides have the same vehicle in their inventory. A Greek Iguana™ is alerted by its laser warning system. This means that a tank has ranged its distance before firing or a laser designator is guiding a laser guided missile toward it. It escapes from the danger by using active protection measures and making a sudden turn. Losses are heavy on both sides, but not catastrophic. Fortunately, NATO's intercession efforts are successful and a truce is established within a week.

IV. FUNCTIONAL FLOWS

A. THE RECONNAISSANCE VERSION OF IGUANA™

1. March to the Operation Area

a) Receive orders to conduct a reconnaissance mission and the intelligence about the operating area. Analyze the orders and do initial planning for operation, which involves:

* becoming familiar with the maps of the operating area and load them into vehicle's database

* updating the intelligence database

* defining the interface requirements with friendly forces

* conducting a "rehearsal" using a digital simulation of the operating area and threat forces

b) Load all consumables (fuel, ammunition, provision etc.) while in the assembly area for a logistics-free operation

* use maximum payload capacity to extend operational endurance

* arrange the storage sites to increase useable internal volume

* modify the modular hardware of the vehicle for a particular mission

c) Conduct fire control system readiness tests and hardware maintenance checks (radios, automatic fire extinguishers, weapons etc.)

d) March through the friendly forces to operating area

* plan the marching route and navigate to the initial location

e) Recover crippled vehicles

f) Coordinate with foremost elements about the enemy situation

* update the intelligence database

* communicate face-to-face with the responsible commander who is directly in contact with enemy

2. Update the Plan

a) Observe the operating area to get more information

* select a convenient position for the observation of the operating area before starting the oncoming operation

* use your long-range sensors and consolidate the other intelligence gathering elements' efforts

* execute counter-reconnaissance functions

b) Identify the critical parts of terrain and select preferred avenues of advance

c) Identify routes for sneaking through enemy lines

d) Get and evaluate the weather report for the time period of the operations

3. Execute the Reconnaissance Mission

a) Navigate according to the planned routes

* check your position and direction regularly

b) Take actions to try to reduce your vehicle's signatures

* make use of terrain, weather conditions and vehicle aspects to reduce the visible, IR, acoustic, radar and seismic signatures of the vehicle

c) Choose successive hiding and observation positions and use camouflage

d) Maintain tight security around the vehicle

e) Move between preselected successive positions rapidly and stealthily

f) Pass through/over or bypass obstacles

* detect the obstacles

* bypass them if possible

* pass them with appropriate approaching technique

g) Ford the rivers or artificial water canals

h) Protect the crew from mines and maintain vehicle mobility

* try to detect minefields and bypass or breach them

i) Provide air-conditioned operating ambience and protect the crew from the NBC threat

* detect contaminated areas and bypass them

* ingest the air from outside and filter it for crew use

* isolate the crew compartment against any infiltration

* provide the air-conditioned operating ambience

j) Detect and identify any weapons designator threat playing on the vehicle and take countermeasures

* execute the evasive maneuvers

* cover oneself with smoke

* jam the incoming missiles

* use decoys for approaching missiles

* enhance your armor protection with explosive reactive armor

k) Gather the intelligence about the enemy units, roads, bridges, residential locations, ground characteristics etc.

* provide the physical retrieval of the intelligence material

l) Detect targets and the actions in the operation area

* find the range and exact location of targets

* classify the type of target

* identify objects to determine if they are friend or foe

* evaluate the immediate threat to the reconnaissance elements from observed targets

* monitor any action of the targets and record it

m) Destroy the targets if observed by enemy

* range the target

* make zoom adjustment, sight switchover and aiming

* fire the weapon

* evaluate the shot

n) Perform reconnaissance with fire if the situation requires

* notice and evaluate the reactions

o) Listen to the enemies tactical radio communications

* record the radio transmissions

* find the direction of the transmission

* use jamming on these frequency if it is ordered

p) Pass collected intelligence simultaneously to the operation center

* use secure communication systems for voice, data, picture transmission

q) Direct the fire support elements on the targets if required

4. Return from the Mission and Report the Reconnaissance Results

a) Choose the hidden receding routes

b) Coordinate the withdrawal with the friendly front elements

c) Deliver an elaborated intelligence report along with the digital recordings of the mission. Debrief the mission results to higher authority

B. THE FORWARD OBSERVER VERSION OF IGUANA™

1. Join the Designated Unit and Coordinate About theOncoming Operations

a) Join the designated unit (tank or infantry company team etc.) in the assembly area

b) Receive the unit's mission and the intelligence about the operating area to make a tentative fire support plan

* become familiar with the maps of the operating area and load them into vehicle's database

* enter the known targets into database

* learn the interface requirements with friendly forces

c) Load enough consumables (fuel, ammunition, provision etc.) while in the assembly area for a logistic-free operation

d) Execute the fire control system checks as well as the hardware maintenance checks (radios, automatic fire extinguishers, weapons etc.)

2. March to the Front Line and Prepare for the Attack

a) Provide early warning to the attached unit against ambushes and attack helicopter raids during the forward approach

* inform the friendly units about the threat direction or location

b) Occupy a camouflaged position and scan the operation area

* use your long-range sensors to consolidate the intelligence gathering elements' efforts

c) Maintain tight security around the vehicle

d) Coordinate with the foremost friendly elements about the latest enemy situation

e) Gather the intelligence about the roads, bridges, residential locations, ground characteristics, minefields etc.

f) Call correction fires to adjust the supporting fires and observe enemy reactions

g) Locate the enemy's defensive lines, tactical command centers and strongholds

* be consistent in use of sensors and time with the unit commander's target priorities

h) Detect the targets and the enemy actions in the operating area

* find the range and exact location of the target

* classify the type of target

* check the friend or foe identification of the target

* try to locate enemy artillery and mortar positions

* observe the operating area and report any hostile action

i) Intercept the enemy's tactical radio communications and try to locate the transmitters

* record the transmissions

* find the direction to the transmitter

j) Pass all of the gathered intelligence to the unit commander in a timely way

k) Plan the preparatory fires and coordinate with all of the fire support elements

3. Attack with the Attached Unit

a) Execute the preparatory fires according to the timetable and evaluate them

b) Join the attached unit and move forward with it

c) Try to reduce vehicle's signatures

* make use of terrain, weather conditions and vehicle aspects to reduce the visible, IR, acoustic, radar and seismic signatures of the vehicle

d) Pass through or bypass the obstacles

* detect the obstacles

* bypass them if possible

* pass them with appropriate approaching technique

e) Ford through the rivers or the artificial water canals

f) Protect the crew from the mines and maintain vehicle mobility

* try to detect minefields and bypass or breach them

g) Provide air-conditioned operating ambience and protect the crew from the NBC threat

* detect the contaminated areas and bypass them

* vacuum the air from outside and filter it for crew

* isolate the crew compartment against any infiltration

* provide the air-conditioned operating ambience

h) Identify any designator threat on the vehicle and take countermeasures

* execute the evasive maneuvers

* cover itself with smoke

* jam the incoming missiles

* use decoys for approaching missiles

i) Detect new targets, call fires on them, give the corrections about the support fires

* find the range and exact location of target

* identify the type of target

* determine the friend or foe identification on the target

* call, coordinate, correct, and evaluate the support fires

j) Execute the unit commander's specific fire support calls (close air support, smoke fires, suppression fires etc.)

k) Report the defensive enemy unit's actions to the attacking commander

* use secure communication systems for voice, data, picture transmission

4. Implement Standard Procedures after the Target Capture

a) Get into a new position and maintain tight security measures

b) Call fire on the receding enemy elements

c) Prepare a defensive fire plan for an enemy counterattack

d) Scan deep into the enemy's operating area and inform the unit commander

about enemy actions

e) Be ready for the following maneuver after parent unit has completed its reorganizing period

C. THE ANTI-GUERRILLA VERSION OF IGUANA™

1. March to the Operation Area

a) Get the operation order and prepare a tentative operation plan with friendly forces

b) Load the consumables (fuel, ammunition, provision etc.) in the assembly area for a logistic-free operation

* use maximum payload capacity to extend operation period

* arrange the storage sites to increase useable internal volume

* modify the modular hardware of the vehicle for a particular mission

c) Execute the fire control system checks as well as the hardware maintenance checks (radios, automatic fire extinguishers, weapons etc.)

d) Escort the convoy of operation elements

* navigate according to the planning routes

* check your position and direction regularly

e) Provide early warning and protection against ambush attempts

f) Protect the crew from the mines and maintain vehicle mobility

* try to detect minefields and bypass or breach them

g) Recover the crippled vehicles

h) Pass through or bypass the obstacles

* detect the obstacles

* bypass them if possible

* pass them with appropriate approaching technique

* ford through the rivers

i) Try to reduce vehicle's signatures

* make use of terrain, weather conditions and vehicle aspects to reduce the visible, IR, acoustic, radar and seismic signatures of the vehicle

2. Search the Operation Area

a) Check the security of operating area prior to the deployment of the friendly forces

b) Determine the critical places and passages

c) Update the operations center about the current terrain and weather conditions

* use secure communication systems for voice, data, picture transmission

d) Control the roads and the entrance and exit of the residential sites

3. Position the Vehicle

a) Move the vehicle to the assigned location

b) Maintain tight security around the vehicle

c) Camouflage the vehicle

d) Stand by for target acquisition

e) Provide air-conditioned operating ambience for crew

f) Intercept the guerrilla tactical radio transmissions and collect intelligence

* record the radio transmissions

* find the direction of the transmission

* use jamming on these frequency if it is ordered

4. Detect the Targets

a) Find the target's exact location and range

b) Classify the type of the target (a sharpshooter, an ATGM or SAM team or guerrilla mortar position etc.)

c) Identify the target as friend or foe

d) Predict the target's possible routes of advance

e) Evaluate the immediate threat level of the detected target for the friendly forces

5. Coordinate with Other Elements

a) Define the engagement time to achieve surprise

b) Coordinate with friendly mobile ambushing teams

* give them the correct guerrilla position and enclosing route data

c) Coordinate with the artillery and mortar units for fire support

d) Coordinate with the attack helicopters and bombardment planes for fire support

e) Report to the operations center the probable guerrilla withdrawal routes

6. Destroy the Targets

a) Sight and fire on the target

* range the target

* make zoom adjustment, sight switchover and aiming

* fire the selected weapon with effective ammunition type

* plot the fall of shot

* evaluate the fire effect on target

b) Channelize and correct the fire support on the guerrilla strongholds and movements

c) Clear the guerrilla strongholds on the rough terrain

* lead the attack when the friendly units are pinpointed by the guerrilla heavy fire

d) Execute the hot-pursuit operation

* don’t lose contact with the guerrillas by maintaining close engagement

e) Keep aware of the operating area with long-range sensors and be prepared to move to gain control

f) Evaluate and report the guerrilla casualties

g) Destroy the guerrilla logistic and training facilities

7. Return to the Base

a) Protect the withdrawing elements

b) Perform the same activities in the “ the marching to the operation area

c) Give the operation records for the feedback, the creation of the new tactics and the training needs

d) Provide the physical retrieval of the intelligence material

V. OPERATIONAL REQUIREMENTS DOCUMENT

A. GENERAL DESCRIPTION OF THE OPERATIONAL CAPABILITY

The tactical usage of Iguana™ Armored Vehicle Family can be classified in the three versions with a few modifications. These three versions are reconnaissance, forward observer, and anti-guerrilla. The reconnaissance version with long-range sensors is planned to conduct scout missions covertly in the highly dangerous modern warfare environments. Its missions are patrolling, monitoring from an observation post, reconnoitering for nuclear/biological/chemical reconnaissance, screening, guarding, providing covering force, providing counter-reconnaissance, tactical raiding, pursuing, conducting armed reconnaissance, providing liaison, providing traffic control, and escorting. Reconnaissance is all about acquiring timely information about an enemy, observing and keeping station on his movements and intentions, and then passing back regular intelligence reports – all of which is best achieved by covert and stealthy means to avoid contact and thus detection. The basic requirement of a reconnaissance force is to survive undetected for as long as possible, especially when conducting deep penetration operations against multi-layered defenses. [Ref. 3] The forward observer vehicle version is planned to participate in combined armored warfare by solving the forward observer's mobility and target acquisition problems. This kind of vehicle is required to automatically create and rapidly disseminate indirect fire plans for immediate execution and synchronization. The most revolutionary version is the anti-guerrilla version. Guerrilla activities gravitate to the rough, swampy, and borderline regions, where conventional forces are inefficient in terms of their mobility, detection, and firepower performance. The increasing performance of modern weaponry (anti-tank guided

missiles, surface to air missiles, sophisticated night vision and communication devices) and its increasing availability to guerrillas along with the possibility of proliferation of NBC weapons increases the operational capabilities of the guerrilla units. Thus, an integrated anti-guerrilla warfare combatant, capable of overcoming some of the inefficiencies of current forces, is in high demand to participate in irregular warfare.

The underlying operational advantage of all Iguana™ versions is its ability to be readily configured to perform in the different operations ranging from anti-guerrilla warfare to the conventional warfare with only minor modifications. The logistic cost incurred by multiple specialized vehicles used today will be minimized by the design of the Iguana™, which envisions significant autonomous operating capability. The weapon, sensor, and communication equipment selections enable the vehicle to react as an integrated combat element. The current alternative vehicles generally focus on one of the basic functions of the Iguana™. However, Iguana™ can be regarded as an integrated combat system with innovative technologic advances rather than a partial solution. Its design must permit all further modifications that may be necessary to keep pace with evolving requirements.

B. THREAT

Combat vehicles will be subject to diverse attacks in the dynamic threat environment experienced during different types of operation. The threat forces will attempt to extend the depth of their attacks through extended range weapons, rapid maneuver, and more sophisticated command, control, communications and intelligence functions.

Border infiltration on the rough terrain by guerrilla groups or drug smugglers creates a serious threat. Closing long borders with limited forces requires combatants that are equipped with the Iguana™ armored vehicles. The Iguana™'s reaction ability against the detected infiltration attempts enhances its deterring effect.

Rapid deployment forces are required to effectively intervene in regional clashes or crises on unknown or poorly known and often rough terrain. Light, air-transportable or airdrop armored units are needed in the rapid deployment forces. Iguana™'s tactical intelligence gathering ability can help to direct the following forces to the expected success areas.

The increasing amount of the UN peace-keeping operations require the combatants with superior detection performance to make timely observations of violations. Combatants also must successfully defend themselves in case of any attack. The peacekeeping missions frequently demand the accurate identification of violators with high-resolution sensors and recording cameras.

The modern warfare playground demands highly maneuverable, destructive, and informed reconnaissance vehicles that can operate independently deep in the enemy territory. The predicted high loses rate of the current scout platoons demands a new kind of reconnaissance vehicle concept that enables the scout crew to detect the targets at long range without entering their opponents detection envelope. However, it is crucial that the tactical intelligence gathered be promptly transferred, but such transfer may be detected. Therefore attention must be paid to information security at both the basic "signature" level as well as in terms of "false information". Thus, these vehicles must be designed to employ electronic warfare countermeasures.

Forward observers in their vehicles will find themselves assigned to move side by side with armored units and detect the targets in the long range. Current forward observer vehicles are not able to operate with the tank units because they can't achieve the same speed or operate on all of the same terrain. Thus, the effective fire support of the armored units can't be implemented and this leads to higher casualty rates.

Land mines will extensively be used to restrict the armor units' maneuver capacity and to destroy them without direct engagement. Most of the casualties in the armored vehicles are due to the spalling problem which occurs when a kinetic energy or shaped charge round impact and penetrates into the vehicle armor. Thus, Iguana™ armor specifications must provide an effective anti-mine protection as well as a reliable solution to the spalling problem.

Today, new top attack smart weapons can easily be launched by artillery and mortar units. Most current vehicles have a critical vulnerability on their tops because the armor protection there is less. Iguana™ is to provide a uniform protection level over the entire armored surface, it can also be helpful to locate these mortar positions with its sophisticated sensors immediately.

C. SHORTCOMINGS OF EXISTING SYSTEMS

The main shortcoming of the current armored combatants is the lack of complete combat system integration for the full spectrum of battlefield threats. They are basically upgraded or modified from the older conceptualized vehicles from the Cold War period. But current asymmetric warfare conditions create a new set of requirements. The new combatants mainly need an autonomous operational capability so that they can move on the different types of ground and destroy targets at extended ranges without being

significant degradation of capability from the changing weather and day/night conditions. It is also obvious that an extensive and simultaneous communication system must be set up for the coordination among the individual vehicles and tactical operation centers. These kinds of data, picture and voice transfers to the operation centers will help the decision-taking process of the commanders.

The reduction of the radar cross section, IR and acoustic signatures for future generations of vehicles is a fundamental necessity for both stealthy tactics and battlefield survival. Flourishing gun and armor piercing technologies compel the consideration of innovative armor protection solutions. The top attack smart weapons that can be easily launched by mortars pose a new kind of threat to the armored units. The bottom and top armor have to be taken into account like the frontal arc armor. Because of the recent advent of 12.7-mm sniper rifles and their potential use for ambushing reconnaissance vehicles, the vulnerability of the light wheeled reconnaissance vehicles seriously increases. The deficiencies of the situational awareness technology on current vehicles seriously degrade their surveillance ability. The sensor and countermeasure combinations for integrated survivability must be able to operate autonomously, while retaining semi-automatic and manual modes. The UAV, satellite and other aerial reconnaissance devices are heavily dependent on the weather conditions. For the close coordination with the attack, scout and support helicopters, Iguana™ must have proper communication, sensor and designator devices to direct the helicopters to the targets. Increasing environmental concerns impose more restrictions on the military vehicles' exhaust emission levels. Military vehicles today must also conform to road safety regulations.

D. CAPABILITIES REQUIRED

1. System Performance

The following standards generally show the minimum system performance requirements to overcome current systems' shortcomings. They are originated from the functional flows of Iguana™. For example, the following system performance requirements are linked to the demanded subordinate functions of the reconnaissance version of Iguana™. These subordinate functions' numbers are shown in parenthesis at the end of each system performance requirement respectively.

a) Iguana™ will have a 700 miles road range.

It can operate in the deep in enemy territory with limited logistic resupply. It must also have a coherent operational endurance range compatible with other armored elements without further refuel and maintenance needs. (1d, 3a)

b) Iguana™ mobility requirements:

* The combat weight of Iguana™ can be up to15 tons.
* It can be quickly transported or airdropped by the transportation planes.
* Iguana™'s gross power to weight ratio will be 25 hp/t at least.
* Iguana™'s road (tarmac) speed can reach 75 km/h.
* Iguana™'s reverse speed can reach 40 km/h.
* Iguana™'s afloat speed can reach 10 km/h.
* Iguana™'s unpaved speed can reach 40 km/h.
* Iguana™ can turn 360 degree within a 9 m external turning radius.
* Iguana™ can turn 360 degree in 8 seconds pivoting time in water.

* Iguana™ can climb vertically up to 1.8 m height in the forward direction.

* Iguana™'s ditch crossing can reach across 1.8 m.

* Iguana™ can climb up a 65% forward or reverse slope on a dry hard surface along the longitudinal axis of the vehicle.

* Iguana™ can cross a 40% dry hard surface side slope and retain its track during side hill maneuvers.

* Iguana™ can accelerate to 50 km/h speed in 10 seconds.

* Iguana™'s unprepared fording depth can reach 1.4 m.

* Iguana™ has a moving ability at 50% slope from the stationary position.

* Deep water fording preparation time by the crew is within 3 minute.

* Iguana™ must be capable of stopping (from maximum speed to a full stop) at a rate of at least 8 meters/sec^2 with minimal side drift (less than 1.5 meters in 15 meters on a dry, level, hard surface).[Ref. 4]

* Iguana™ driver can adjust the peak pressures under the wheels to improve mobility in the soft soil and deep snow conditions while it generates minima disturbance of terrain.

* Because of the likely rough-terrain and night operating regime, rollover stability is a vital priority for Iguana™.

* A clear rearview of the vehicle from the driver's instrument panel will allow rapid evasive maneuvers to be carried out.

All of these parameters are related to the need for superior physical agility and obstacle passing capacity. Iguana™ is considered because of its nearly unique ability to operate over a diverse combination of terrain under diverse weather conditions where the current vehicles have serious mobility handicaps. (1d, 3a, 3e, 3f, 3g)

c) Armored vehicles must possess fully automated contamination avoidance sensors that provide early warning for the full spectrum of radiological, chemical, and biological contaminants. These detectors must categorize and classify contaminants,

determine the degree and the location of contamination, and possess sufficient sensitivity to permit a maneuver force to avoid contaminated areas. (3i)

d) The maximum dimensions of Iguana™ will be:

Width = 2.5 m, Height = 2.5 m, Length = 6 m

The dimensions can't expand beyond these values because of the low silhouette, minimum exposed target signature and transportation considerations. Iguana™ hull design must facilitate amphibious operations. (3b, 3g)

e) Target range determination must be between 200-10000 m with +/- 5m tolerance while target discrimination is 20 m between targets. The destruction of a target mainly depends on the correct range data input to fire control system. (3l)

f) Iguana™ adjustable ground clearance can be between 20 cm and 50 cm. It enables Iguana™ to adjust itself in a firing position at the optimum level to reduce its exposure to the enemy eye. It also helps to move on the different terrain types accordingly. (3b, 3e)

g) Sensor specifications:

* The sensor suite must meet a 95 % probability detection and recognition standard in the 1 dB/km atmospheric attenuation condition by meeting the following target range requirements:

Tank, APC, and helicopter target detection range must be 10 km. while their recognition ranges are 3.8 km. The 10-km detection range generally gives enough time to verify the target identification with other means and to clarify the enemy intentions. It is also enough distance to direct and correct the friendly support fire on

them. The 3.8-km recognition range is generally beyond the effective tank gun and anti-tank missile threat distance thus reducing the Iguana^{TM} risk of being engaged.

For personnel targets, the detection range must reach 4.8 km. with a 1.24 km recognition range. The 4.8 km detection range for personnel detection is enough to verify target identification with other means, to understand the tactical situation, to prevent security perimeter penetrations, to open direct fire on them, and to channelize the support fires, for example, mortar fire onto them. The 1.24 km recognition range gives enough tactical flexibility to protect friendly troops from the effects of heavy machine gun fire, sniper fire, and light anti-tank weapons.

* Iguana^{TM} must have the capability of designating missiles to targets and conducting detailed damage/kill assessments on them.

* Iguana^{TM}'s sensor suite can operate above the trees and knolls to observe enemy activities without completely exposing the entire vehicle.

* Iguana^{TM}'s sensor suite must be protected from artillery and mortar shell fragments without obstructing sensor apertures.

* The sensor suite must have 0.1-mrad line-of-sight stabilization to compensate adverse high frequency random motion (jitter). Jitter reduces target recognition range for resolution-limited systems by negatively corrupting high spatial frequencies.

* Sensor sights must also function as engagement sights. While wide field of view (WFOV) is used for search and target acquisition sight, narrow field of view (NFOV) can be used for the engagement and damage assessment sighting.

* Sensor platform must perform effectively day or night in adverse weather,

in cluttered background environments, and in the presence of countermeasures that include screening, jamming, and the use of low observable and active defense systems.

* The sensor suite must have the ability to conduct:

automated wide–area search (sensor scan sector can be limited in 10-180 degrees of axes while the center of this sector can be freely selected within 360 degrees)

automated target acquisition, and prioritization

automated tracking at extended ranges.

Automation of these capabilities reduces crew workload, shortens engagement timelines to acquire targets, and as a result increases the effectiveness of direct fire. The ability to acquire and hand over targets automatically, supports the design goal of a combat vehicle with fewer crew members that is more lethal and more deployable with improved situational awareness on the digitized battlefield. (2a, 31, 3n)

h) Iguana™'s low detectable multi-spectral signature (visible, infrared, radar, seismic, and acoustic) will be as critical as its armor technology for the survival concerns.(2c,3b,3c)

g) A stabilized turret will have a 90 degrees per second slew rate in elevation and traverse direction. Its angle of traverse will be 360 degrees while its angle of elevation is between –10 and +65 degrees. A manual back-up system in addition to the electro-mechanical turret control is essential. Destruction of different types of targets at 3 km requires combined weapon systems in the turret. The fire-on-the-move capability (turret stabilization system) against both static and mobile targets will provide a robust

effect on the gunnery. An armored vehicle must have self-defense ability at minimum for the independent operation capability.(3m,3n)

j) Iguana™ must provide a standard armor protection against 14.5-mm heavy machine gun rounds and artillery splinters. Additional ballistic protection kits can enhance the survivability against the 30-mm Armor Piercing Fin Stabilized Discarding Sabot (APFDS) rounds fired from a 1000-m. range. Even if stealth characteristics are achieved, the total defense system of Iguana™ can't be solely dependent on them without an effective armor protection. Armor will continue to play a significant role in the survival concept.(3h,3j)

2. Logistics and Readiness

a) The proposed crew number is three. Driver is mainly responsible for the control of the vehicle's motion. The gunner's main missions are engagement of targets and the operation of the sensor suite. The commander is mainly responsible for the management of the engagement and the communications. He is also capable of using the weapon systems in emergency situations. The reduced crew number allows the Iguana™ design to achieve a lower profile.

b) The armored vehicles sometimes are crippled on rough or slippery terrain. Iguana™'s must recover each other with the help of their towing equipment.

c) Without removing the turret, the engine shall be removable with the help of a recovery vehicle and crew on all terrain conditions in two hours. This will increase the operational readiness of the vehicle.

d) The automatic fire suppression system's reaction time must be under seven

milliseconds. If the vehicle has been shot, this system will increase the survival probability. Moreover, an automatic engine shutoff system, in case of fire, may save the vehicle. The important design issue is the definition of the correct fire detection threshold values to avoid false alarms for the automatic fire suppression system.

e) The engine cooling system performance is critical in hot climate conditions. The presence of heavy dust and sand impose great demand for a higher air filter capacity for Iguana™. However, in the very cold regions the prestart heating of the engine may be necessary before cranking engine.

f) The quantity of stored ammunition must be large enough to support independent operations of duration 3 days with 2 major encounters. An isolated ammunition storage compartment will enhance survivability.

g) Iguana™ will require greatly improved electrical power generation, storage, switching, and distribution. These systems must be capable of providing the electrical power to the different subsystems of Iguana™ such as the electric drive system and the command and control system. Electrical power components must be sized and packaged for efficient vehicle application, thereby requiring increased energy densities. They must not introduce human health hazards or unnecessary system vulnerabilities.[Ref. 4]

h) All of the electronic devices are considered as functional between –40 C and + 50 C climatic temperature ranges. Their resistance to the extreme moisture and barometric situations is also important. The vehicle electronic infrastructure must protect from the nuclear explosion electromagnetic pulse.

i) On-board storage sites designed for the camouflage net, water cans, provisions, crew belongings etc. Iguana™ must be able to accept sufficient power from an external source to start engine, run diagnostic routines and to activate its sensor suite.

j) From a non-operational status (non-operational for at least 4 consecutive hours), upon application of power, Iguana™ will be fully mission capable (i.e., able to move, communicate and perform surveillance and survivability functions) within 3 minutes. From a warm status, it must be fully operational in 10 seconds.[Ref.4]

2. Critical System Characteristics

a) Passive missile and laser warning sensors with active electronic and IR countermeasures will improve battlefield survivability.

b) Secure tactical communication nets (includes air-ground communication) must be operational with a 40 km range. The netting of the vehicle with outside infantry directly contributes to operational efficiency. Enemy radio intercept and jamming are always big handicaps in armored warfare.

c) Intentional or unintentional loss or interruption of system power must not cause non-recoverable loss of critical mission data from the on-board electronics system. But there must be quick deletion process in case of the vehicle's capture by the hostile forces.[Ref. 4]

d) The design and construction of Iguana™ must minimize safety and health risks to operators, maintenance and support personnel.[Ref. 4]

e) System design and configuration will be based on incorporation of "enablers" which will facilitate application of matured technologies and/or allow for growth in the following areas [Ref. 4]:

* Addition/modification of electronic components (hardware and software)

* Propulsion system, suspension and frame to permit system combat-loaded weight growth of 15 percent

* Application of improved armor

* Addition of electronic vulnerability reduction measures without redesign of the electronic network

* Biological agent detection

E. INTEGRATED LOGISTIC SUPPORT

1. Maintenance Planning

Iguana™ will use the four level maintenance concept consisting of the unit level, direct support (DS), general support (GS), and depot level maintenance. Maintenance is characterized by quick turnaround and repair replacement of components, modules, or units will occur at the lowest possible level of maintenance. Periodic maintenance is scheduled according to the mileage accrued.

a) Unit level maintenance: Operator/crew will focus on diagnostics/prognostics using on-board equipment. Unit mechanics will focus on diagnostics/prognostics repairs using more capable equipment and repair with replaceable components and/or modules.[Ref. 4]

b) Direct Support (DS) maintenance: It is characterized by mobile maintenance support teams who can do fault diagnosis and perform maintenance functions. DS maintenance will repair "common/quick fix" equipment failures on the critical weapons systems.[Ref.4]

c) General Support (GS) maintenance: It is characterized by commodity repair of components and end items. GS maintenance units will repair by component replacement, repair components for replacement or repair replaced components for return to the exchange point for future reissue.[Ref. 4]

d) Depot level maintenance support: It is characterized by overhaul and repair of end items, components and modules, and repair which exceeds the capability of lower maintenance levels.[Ref. 4]

2. Support Equipment:

a) The vehicle must have enough on-board equipment for the basic tests and repairs like track repair and adjustment. Towing tools and position fortification equipment are also important. The recovery vehicle must possess the elaborate enough repair tools to remove and replace the engine.

b) Automatic system checks, modular changeable subsystems, warning spotlights on the instrument panel, automatic security fuses for operational failures are useful design features for maintenance and operation. Easy access to periodic maintenance spots will minimize the repair time.

c) The average operation available period percentage must exceed 90% against the overall maintenance period.

3. Human System Integration

a) Air-conditioned operating environment is required.

b) Ergonomic seating places and controls are critical for crew performance.

c) Iguana™ crew must undergo at least 6 month basic and crew training on the vehicle and its combat system.

d) Gunner must demonstrate capability taught in the basic driver training course.

e) Simulator training will enhance the crew performance during the force-on-force combat training.

f) Periodic field exercises will consolidate the simulator training.

g) The teaching of operational safety measures must take a high level priority during the training period.

h) Laser engagement systems can be integrated into field exercises.

i) The vehicle software must be designed so that fault entry logic can detect errors in order to minimize incorrect crew entries, which could cause a hazardous situation. [Ref. 4]

4. Computer Resources

a) Iguana™ must have on-board computer resources for decision aids such as automatic updating of overlays on the tactical map display, position and navigation control, automotive control, weapons control, self-defense systems, communication processing, diagnostic/prognostics, maintenance and operator/maintenance training. The centralized data processor nods will increase the capacity usage and the vehicle's computer system will have enough flexibility to conduct its functions in case of any partial failure.

b) Iguana™ is planned to gather intelligence by using its own sensors. The storage and distribution of this intelligence take must be supported by a strong database and network capability.

5. Other Logistic Considerations

a) Iguana™ must provide a means for routine inspecting, testing, and cleaning of subsystems without removal of major assemblies. [Ref. 4]

b) Technical maintenance manuals must be prepared in detail.

F. INFRASTRUCTURE SUPPORT AND INTEROPERABILITY

1. Command, Control, Communications, & intelligence

a) Iguana™ must interface with the command, control, communication and intelligence architecture of the other armored unit elements.

b) Iguana™ must be capable of transmitting and receiving secure digital data and operating on two secure voice radio communications nets.

c) The system must provide warnings. These warnings must not interrupt mission critical functions (move, communicate, surveillance and survive), unless it creates unsafe or hazardous situations.[Ref. 4]

d) Iguana™ sensor images can be displayed in the aiming and observation screens in real time and recorded for later analysis and training feedback.

e) It is critical for Iguana™ to have a clear inter-vehicular communication that can be joined by the outside infantry.

2. Transportation and Basing

The maximum combat weight limit is decided set 15 ton. This limit allows for airdrop operations. For rapid deployment operations, air transportation ability of Iguana™ supports the vehicle's deployment flexibility. Sea, rail and road transportation options must negotiate with the NATO standards. Iguana™ must be tried to use its own mobility only in the actual operation area. The basing facilities will include the

maintenance and supply units for Iguana™. It must be located as close to the operation area without lessening the security criteria.

3. Standardization, Interoperability, and Commonality

a) Iguana™ will use standard battlefield combat identification system procedures and equipment to reduce the potential for fratricide.

b) Standard components, parts, tools, fasteners, fuel type and test equipment will be used to the maximum extent possible. [Ref. 4]

c) Iguana™ will be a metric based system.

4. Mapping, Charting, and Geodesy Support

Iguana™ must have an on-board self-locating capability with an on-board tactical display to assist the crew in selecting and navigating from one position to the next by using the hybrid navigation systems. [Ref. 4] Digital map data support related to the operation area is required.

5. Environmental Support

Room temperature and low level moisture environment is necessary for the depot level storage. There is no special environment support activity except arctic regions.

G. FORCE STRUCTURE

The proposed force structure of the system will change for the different versions of the Iguana™. The Iguana™ number in the artillery battalion will depend on the observation team number (usually 3 or 4). For the reconnaissance version, the number can reach 12 in a cavalry company. The anti-guerrilla version can be used at least as a section (2 Iguana™). But the number can become 4 in a platoon for the administrative and maintenance considerations.

Suppose that you try to equip 10 armored brigades with Iguana™s. The cavalry companies of the armored brigade needs 12 reconnaissance version of the Iguana™. The armored brigade fire support forward observer team number can be 13 similar to the number of maneuver company teams in the armored brigade. Moreover, if you try to firmly control the orange country border against any guerrilla infiltration, then the following logic applies. This border sector is 250 km long and generally has a mountainous character. The border security battalions are covering an average 25-km section. Each battalion needs a platoon of 4 Iguana™s to close its portion of the border against the guerrilla infiltration and raids. So the required number of the anti-guerrilla versions is 40. The total force structure consists then of 120 reconnaissance Iguana™s, 130 forward observer vehicle Iguana™s and 40 anti-guerrilla version Iguana™s. Thus the total Iguana™ force level would be 290 in the mix described.

H. SCHEDULE CONSIDERATIONS

When the delivery order of the Iguana™ fleet is considered, the following schedule can be proposed for the 290 Iguana™ acquisition. Software will be developed in conjunction with the development of this system, as will appropriate embedded training manuals, repair parts lists, and special tools list. The building of the manufacturing facilities (1 year) and the basic training period on the vehicle (6 months) can also be carried out simultaneously along the following steps.

1. The mission and operation requirements study: 1 year
2. The combat system design and configuration process: 2.5 years
3. The prototypes' production and the test and selection process: 1.5 years
4. Serial production of the 290 Iguana™s: 3 years

5. Total time for bringing a force of 290 Iguana^{TM}s into service: 8 years

VI. THE APPLICATION OF COMPOSITE MATERIALS IN THE ARMORED VEHICLE CONSTRUCTION

The application of lightweight thick composites in armored land combat vehicles will overcome the current conventional metal vehicle construction problems. Composite armor usually consists of glass laminates and matrix material. It can be also covered with ceramic tiles for better penetration resistance. The curing temperature and the temperature gradient, the applied pressure and the pressure gradient, and curing duration are important parameters in composite armor manufacturing processes. The residual stresses can be controlled during the manufacturing phase and lead to control of direction of propagation of the high velocity impact shock. For long life cycle service, the elimination of air pockets in the composite armor is very critical. Otherwise, the infiltration of moisture to these air pockets quickly leads to a delamination of the composite armor. Friction with the metal components, like the vehicle's track, can damage the composite material. Covering these parts of the armor with a protective layer of metal reduces this wear. Another important manufacturing criteria that must be taken into consideration is that lengthy exposure to ultraviolet radiation can decompose the composite material integrity. In the view of the developers of composite armors, the main obstacle to its extensive use in armored vehicles is the reluctance of the tank designers and constructors to adapt themselves to this new technology. They would be forced to change their production processes, workforce and the metal-based knowledge to those of the highly competitive composite-manufacturing environment. The composite vehicle benefits over the metal hull construction can be illustrated in the following aspects:

1. Composite armor provides superior crew survivability in the modern battlefield. The fiber reinforced polymer composite structural armor exhibits higher damage tolerance than the conventional armor protection. The tensile strength, compressive strength, specific stiffness and flexural strength values of composite armor are better than rolled homogeneous steel armor (RHA) even if RHA incorporates ceramics. Composite armor protection performance will significantly increase when it is used with explosive reactive armor plates. The spall suppression in the composite armor reduces the crew casualty by limiting the spallation spray area. It also lifts the spall liner requirement.

2. The reduced thermal, radar and acoustic vehicle signatures of composite armor decrease the probability of being detected by enemy. Composite armor provides a significant hull weight reduction to accommodate increased swimming, fuel, ammo storage, add-on armor performance improvements. The structure and armor of Iguana™ will weigh at least 33 percent less than comparable steel or aluminum. It also enhances rapid mobility and deployment capability for the armored vehicles.

3. Composite armor has much higher insulation against tropical and arctic climates due to the low thermal conductivity. While it supports the thermal signature reduction, it also enhances the crew protection from the harsh climate conditions.

4. Composite armor has high damage tolerance and multi-hit capability because of the higher energy absorption capacity. It has the higher fatigue strength and lower fatigue crack growth rate. It is resistant to high shear stresses.

5. It has higher damping and reduced vibration amplitudes. Much of the noise in armored vehicles is caused by metal hull vibrations when the engines are running.

Composite armor approximately provides a 50% reduction on the interior vehicle crew space noise level. So the acoustic noise attenuation in composite armored combat vehicles increases the crew intercommunication efficiency and reduces the crew fatigue because of the low noise level.

6. It is highly resistant to chemicals and solvents (sulfuric acid, hydrochloric acid etc.) compared to steel and aluminum.

7. It exhibits superior explosive blast resistance against mine ruptures in the belly armor of the armored vehicle.

8. It is highly flame resistant (self-extinguishing) with extremely low smoke generation because of the high content of glass laminates.

9. It has maintenance kits for easy repairability and nondestructive testing methods for failure diagnosis.

11. The molding of complex shapes is much easier than in metal in terms of structural integrity.

12. It supports reliable, repeatable and accurate modular composite part fabrication by making easy bonding process with ceramic tile.

14. The unit cost of the composite armored vehicle is more economical in the large quantity serial production (500 or above) than that of the metal hull vehicle production.

15. Composite laminates are not susceptible to galvanic corrosion since none of its constituents appear in an electromotive series.

VII. HYBRID DRIVE SYSTEMS FOR THE ARMORED VEHICLES

Although the idea of electrically powered military vehicles has been around since 1940s, recent technologic breakthroughs have made the idea more plausible as a viable alternative to the internal-combustion-engine-powered vehicles. Hybrid electric engines use a combination of electrical power and conventional fuel to improve power and fuel consumption. The acceleration of the conventional fuel vehicle from a stop requires more fuel which means more exhaust gases produced. However, the electric motors generate full torque from a stop and waste very little energy while idling. The electrically driven armored vehicles have very high peak operating capabilities while an on-board intercooled-turbocharged motor generator maintains the energy reserve of the traction battery system. The vehicle never has to be recharged from an electrical power source. The internal diagnostics/prognostics systems and modularity facilitate the maintenance process. It operates solely from the conventional diesel fuel. Because of the high operating efficiency, fuel economy of the vehicle is more than doubled and the common fuel logistic concerns of the armored warfare are significantly reduced while the same operating range of the armored vehicle is maintained. In addition, the airborne emissions are also dramatically lowered.

The hybrid vehicles produce no exhaust plume in electric mode. The electric drive motors that support thermal management with a liquid cooling process run quietly and radiate little heat to be detected by infrared cameras or sensors. It has the capability of silent watch operation for extended periods of time. The acoustic signature of the vehicle will be reduced more significantly if the vehicle is fitted with rubber band tracks. The vehicle engine exhaust can also be minimized through special exhaust ducting for the

lower infrared signature. While stationary, the hybrid-electric vehicle engine and generator can be used to supply electric power for the command posts in the field. Because of the digitized drive-by-wire controls, the hybrid electric driven vehicles can be easily adapted to the unmanned-robotic surveillance and reconnaissance operations for highly risk missions. The all-electric servo drives that are digitally controlled are preferable for armored vehicle turrets rather than the electrohydraulic drives. While this improvement enhances the stabilization accuracy and fire protection, it is also coherent with the innovative hybrid and robotic technologies.

Hybrid electric propulsion technology is highly favored for its internal volume and design-flexibility advantages. The electro-mechanical transmission that replaces the standard hydro-mechanical transmission systems consists of a generator coupled directly to the vehicle's engine and separate motors driving each sprocket of a tracked vehicle, the only connection between the generator and the motors being electric cables. The independently controlled lightweight compact permanent-magnet brushless direct-current electric motors have microprocessor-controlled inverters. These motors consist of a rotor with rare-earth permanent magnets mounted around the stator and relatively thin but larger in diameter than conventional DC motors. They can produce more torque and their torque based traction control assures smooth vehicle operation. The gear change requirements can be eliminated by the phase advance controls. To minimize the space taken up by the transmission within the hull, the electric motors can be located externally. The trailing road wheels transmit the drive to the tracks and eliminate the sprocket drive requirement. The unison regeneration method allows the maximum power generation. Because of much higher power density, the power electronics incorporate Insulated Gate

Bipolar Transistors (IGBTs) which, in turn, reduce cooling requirements. This contributes to the total volume reduction of the transmission. Further reductions in volume are expected to come from the development of silicon carbide semiconductor devices, which are capable of operating at higher temperatures. The classic type of electric transmission in which the generator and motors are only connected by cables enjoys several advantages over mechanical or hydro-mechanical transmissions but there is a problem with it in tracked vehicles. This problem arises from the fact that in tracked vehicles transmissions are used not only in propulsion but also for steering; if this is to be done efficiently large amounts of power have to be transferred from one track to the other. This means that the driving motors also have to act at times as generators, which can be arranged without difficulty. However, the amounts of power regenerated at the inner track during a turn and transferred to the outer track are large; for this reason the motors of electric transmission with regenerative steering have to be significantly larger than they would be if they were only used for propulsion. An innovative electro-mechanical transmission in the figure 1 can be considered to overcome this problem. [Ref. 5]

Superior acceleration and top speed capabilities of this technology enhance the agility of the armored vehicles. It enables the armored vehicle to realize rapid starts from a stop without the delay of starting the gas engine. To change positions quickly and to rush forward to the target in the minimum time exposed to enemy eyes are some of the tactical engagement advantages. The vehicle can travel an additional 30-km distance in electric mode using the present lead-acid battery package. The available power is also sufficient to operate on-board equipment such as radars, radios, and lasers. When

operating in the stealth mode, without running the on-board recharging motor-generator, the armored vehicle is quiet, cool, and emits no exhaust. This ability will improve the silent creeping capability of the vehicle to maneuver in on the enemy positions during scout missions or in tactical raids. The maintenance-free sealed lead-acid batteries use the co-extruded composite matrix technology that creates a lead-coated glass fiber wire woven into mesh. The mesh is coated with an active material, cut into grids, separated by absorptive glass fiber mats and stacked in a reinforced box. The woven grid design is configured in multiple shapes and sizes to meet a wide variety of energy storage requirements. There are also some trials about the adoption of lithium-ion or nickel/metal hybrid batteries to increase the all-electric range.

The field trials for the integration of electric drive into the prototype HMMWV, M113 APC and Bradley IFV are being conducted. There are also application plans of this technology under consideration for the modified versions of M-1series Abrams tank. Future work will strive to refine this technology to further improve its performance and to integrate these concepts into other vehicles identified for future battlefield environments. There are some efforts to improve the electro-magnetic and electrothermal-chemical guns as well as electromagnetic armor for the armored vehicles. The basic ingredients of hybrid electric drive systems can be used jointly by these guns to create an "all-electric" armored combat vehicle.

Figure 2 shows the principal components of an electro-mechanical transmission. While Figure 3 shows the main components of a hybrid electric drive system for armored vehicles, Figure 4 shows the prototype hybrid electric propulsion Bradley Infantry

Fighting Vehicle (IFV) with a 275 kW diesel-engine auxiliary power unit in the following page.

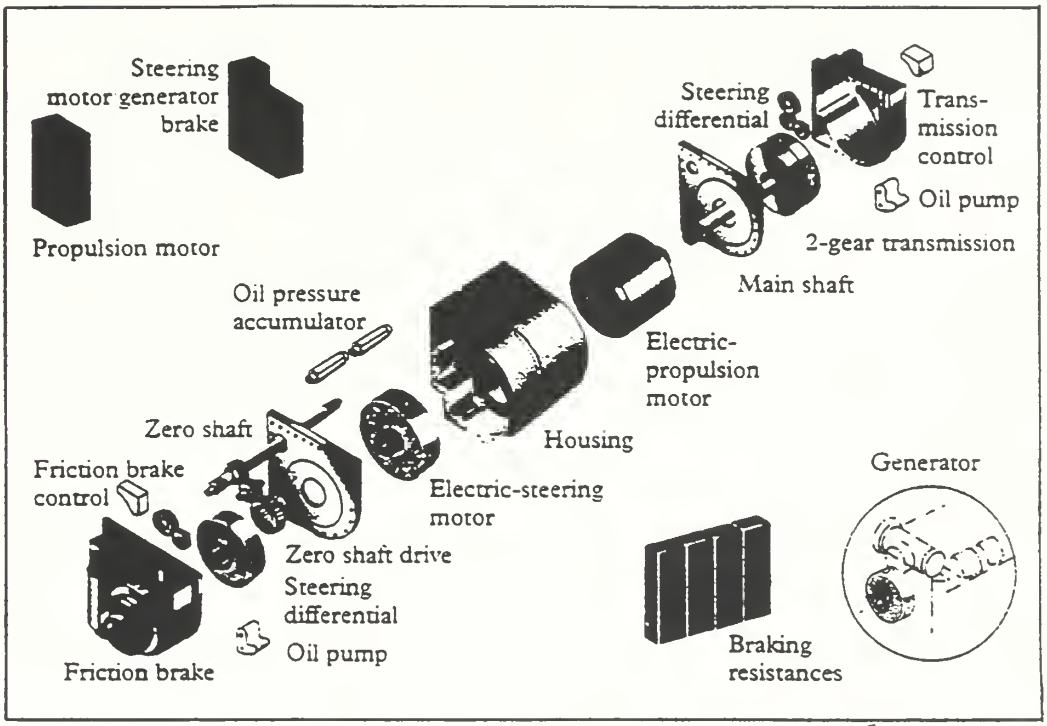


Figure 2. The principal components of the Renk EMT 1100 electro-mechanical transmission (from JANE'S INTERNATIONAL DEFENSE REVIEW 1/1999)

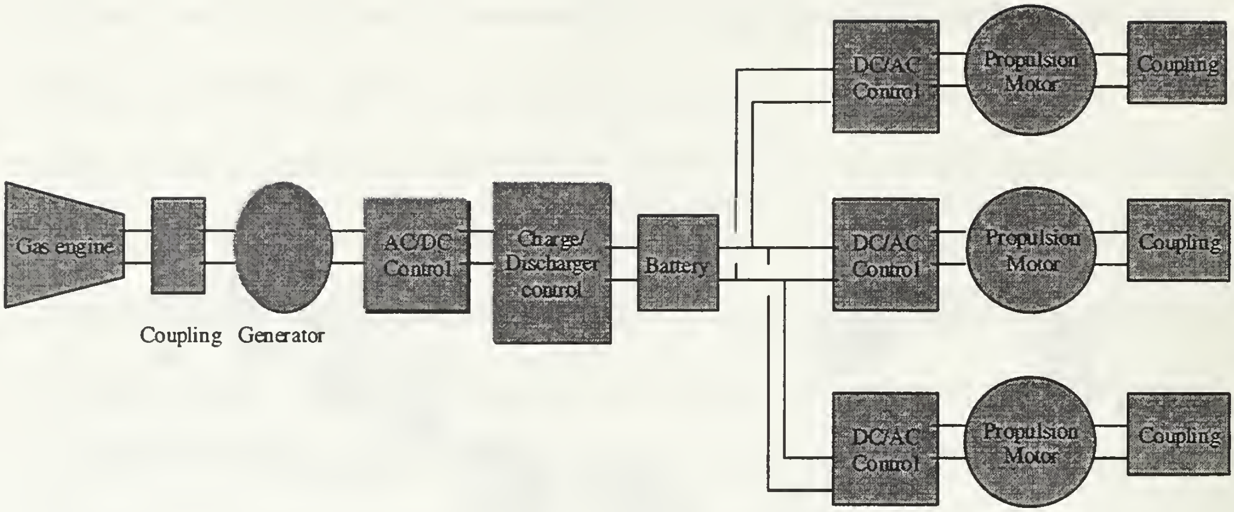


Figure 3. Hybrid Electric Drive System Main Components

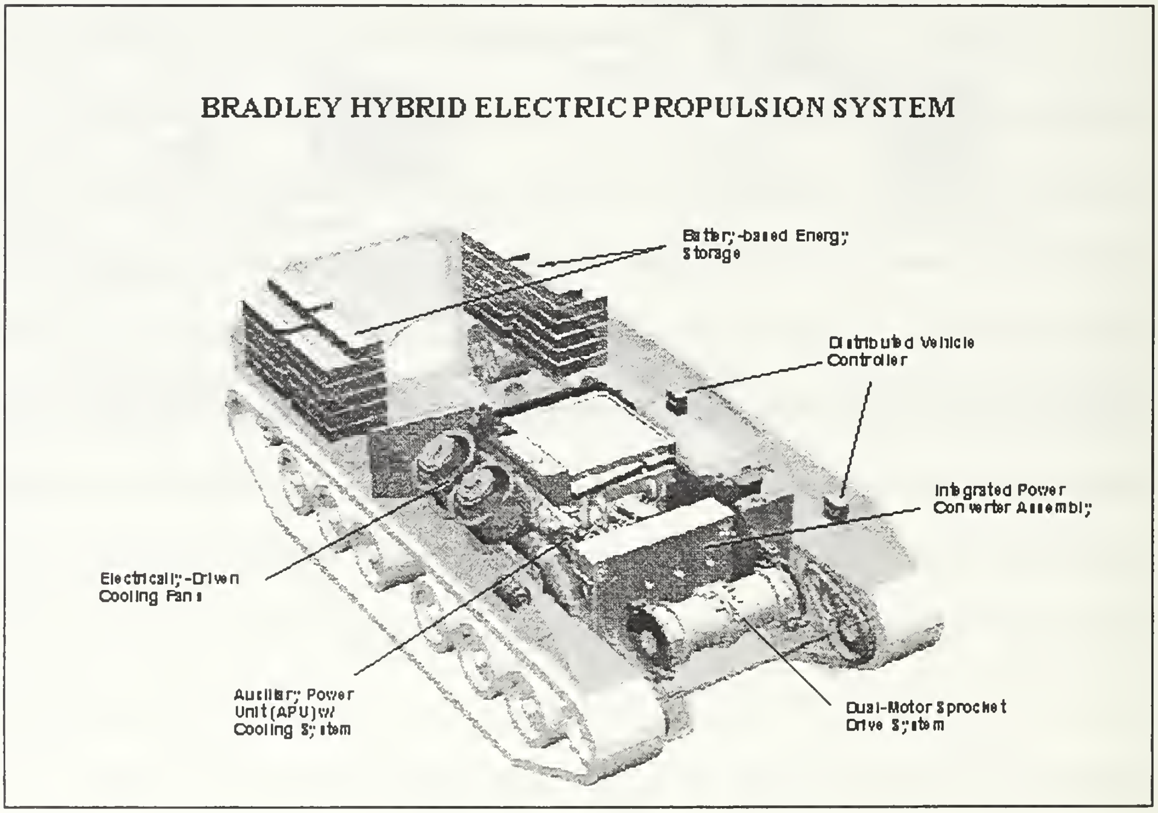


Figure 4. Prototype Bradley Hybrid Electric Propulsion System
(from www.tacom.army.mil/tardec/electric_drive/bradley/sld001.htm)

VIII. THE COMPARASION OF THE POSSIBLE ELECTRIC DRIVE SYSTEM COMPONENTS FOR ARMORED VEHICLES

A. ELECTRIC MACHINES

1. Direct Current (DC) Machines: They are physically larger due to the presence of a commutator and brush assembly. This also contributes to high initial and maintenance costs. The commutator also imposes a limit on the maximum machine speed and contributes significant electro-magnetic interference (EMI) concerns. DC machine control is simple but the large volume and low torque density makes it unattractive for compact systems.

2. Reluctance Machines: Its design is simple, cheap and rugged. The power factor is poor resulting in the requirement of larger devices in the power converter. Since there is no excitation on the rotor, the air gap is relatively small. This is an unattractive feature for a machine in a high-shock environment due to the possibility of stator and rotor coming in contact.

3. Field Wound Synchronous Machines: They require a separate DC source for the rotor winding and occasional maintenance on the brushes and slip rings. Since the rotor is excited, the air gap will be fairly large, improving reliability in a high-shock environment. The field winding facilitates control of terminal voltage or power factor. This type of synchronous machine is often times used in high-power low-speed applications, such as ship propulsion, where the machine's torque density has no rival.

4. Induction Machines: They require relatively small air gaps since the rotor currents must be induced from the stator-derived rotating magnetic field. Despite this negative regarding shock performance, induction machines are cheap, rugged and require

little maintenance. The efficiency is generally lower than a synchronous machine and it must always operate at a lagging power factor. Induction machines are used in many electric drive applications for commercial vehicles.

5. Permanent Magnet (PM) Machines: Since high energy density magnets supply the rotor excitation, the air gap of PM machines may be large to permit its usage on moving platforms. These machines, which have small volume occupation characteristics, operate at high efficiency, high power factor and have a high power density. Despite high initial cost, PM machines are steadily displacing induction machines in medium-power electric-drive applications such as military vehicles.

B. POWER CONVERTERS

1. Pulse Width Modulation (PWM) Inverter: It is a mature technology whose control is straightforward. The harmonics produced by the converter are well defined and can be made small by going to higher switching frequencies. This results in very sinusoidal machine currents and therefore very little torque pulsation. Since there is typically a capacitor at the input, regenerated energy must be accounted for by additional control mechanisms. It is commonly used in the hybrid electric drive systems.

2. Current Source Inverter (CSI): It uses older SCR technology, which introduces some commutation issues. It may be load commutated when operated with an over-excited field-wound synchronous machine, but otherwise, additional forced commutated circuitry is required. At high power PWM operation is generally not possible and torque pulsation may become prohibitive. In addition, the quasi-square wave machine currents lead to losses in the machine that requires derating. One particular advantage of the CSI

is that regeneration is straightforward. The CSI is used in very high power applications together with the field-wound synchronous machine.

3. Cycloconverter: Its structure is rather complicated with numerous semiconductor devices. It operates at a relatively poor power factor and introduces considerable issues regarding harmonics. It also has attractive regeneration characteristics but it tends to be a larger converter due to the additional filters and isolation transformers that are required. Cycloconverter drives are found in the large ship propulsion drives.

C. POWER DEVICE TECHNOLOGIES

1. Silicon Controlled Rectifier (SCR): It has no direct control of turn off.

2. Bipolar Junction Transistor (BJT): It provides limited switching frequency.

3. Field Effect Transistors (FETs): Despite facilitating the highest switching frequencies, these devices do not commonly have a high enough current rating to be found in high power electric drive applications.

4. Insulated Gate Bipolar Transistors (IGBTs): It is suitable for high power applications and it has relatively high switching frequency.

5. MOS Controlled Transistors (MCTs): It very new technology. It can be applicable for future hybrid drive systems.

IX. MOBILITY ANALYSIS

Future armored vehicles must possess the tactical, operational, and strategic mobility and agility required to survive and to dominate the maneuver battle. This requirement includes the ability to rapidly move cross-country and on roads, in all natural and man-made environments to include water obstacles. Key components of tactical mobility include speed, acceleration, obstacle (including mines) detection and avoidance, NBC detection and avoidance, and armored vehicle suspension systems capable of stabilizing the platform to within crew, weapons, and structural specific requirements. Operational mobility includes resupply frequency, number of required maintenance or rest halts, similar tactical mobility levels for all members of armored unit, and ability to operate with infrastructure (such as bridge or tunnel) constraints. Strategic mobility includes sea, rail, air, and road transportability as well as logistical requirements. Future armored vehicles must be able to rapidly deploy into primitive theaters of operations and execute combat missions immediately, with little or no infrastructure or logistic support. Enhanced mobility adds greater flexibility to armored units, allowing them to take action faster than an enemy can react. It also gives the armored unit commander more options in terms of friendly courses of action. This capability increases the lethality and survivability of armored units, allowing quicker results on the battlefield with fewer friendly casualties.

Iguana^{TM}'s mission theater is extended to the rougher terrain where current conventional vehicles normally can't operate. So physical agility is an important parameter along with self-sustainability. The disadvantages of sandy, muddy, and swampy terrain conditions for the mobility of most current vehicles are generally

compensated by the Iguana™'s design. The amphibious ability of Iguana™ enables it to perform fording operations easily. This mobility versatility with the high detection means gives it superior battlefield surveillance and domination abilities in an unprecedented set of geographic locations and climatic conditions. Iguana™ must have proper design and necessary tools for the transportability on roads with the wheeled transporters for the long ranges. Depending on the future heavy-lift helicopters' lifting capacity, the transportability with heavy-lift helicopters across battlefield arena can increase the operational flexibility largely. Iguana™ mobility components include transmission, engine, suspension, tracks, wheels, and fuels and lubricants. The use of several advanced component systems such as band track, semiactive suspension with an active track tensioner, and electric drives improve tactical mobility. Iguana™'s hybrid electric drive will improve fuel economy. The continuous band tracks will be developed for vehicles as heavy as 25 tons, providing the enhanced on/off road mobility through reduced ground pressure, better traction and lateral stability; reduced platform vibration, noise, radar/acoustic signatures, weight, and rolling resistance; improved track life; corrosion and maintenance-free operations; and lower life cycle costs. [Ref. 6] Its nitrile rubber based track material will satisfy long service time requirements. There are still design problems in changing the continuous band track in field conditions by the crew. Otherwise, the traditional track design with some modifications can be used for Iguana™ while it is a mandatory selection for main battle tanks because of the gross vehicle weight. The front drives sprockets engage with rubber-bushed, double pin tracks that can be up to 50 cm wide and have links with two replaceable road pads each. They are the new generation tracks with sprocket engagement into the track link bodies instead of end

connectors. As a result of the latter they are no longer subject to wear, which is confined to the link bodies, and the track retains in full its functional characteristics to the end of its working life. Semiactive suspension will be developed incorporating a track tensioning system that will provide improved fuel economy and better track retention. The increased number of road wheels will increase the length of the track in contact with the ground, and consequently reduce the nominal ground pressure (NGP). More importantly, it will reduce the peaks of the ground pressure which occur under the road wheels and which govern, to a large extent, performance on the soft ground. Active noise and vibration control will minimize the noise signature and vibration signature as well as the crew fatigue. Composite armor and hybrid electric drive will also significantly enhance the noise and vibration control performance. The reduced dust signature of Iguana™ due to the side skirts will contribute to its stealth operation performance. The Iguana™ must be able to autonomously and quickly detect and breach or bypass minefields. So a dozer blade (interchangeable with mine plough) can enhance its mobility performance.

Iguana™ must fulfill all of the Operation Requirement Document mobility specifications in the section D1 of the chapter V. In addition to this, the long-term service and RAM (Reliability, Availability, and Maintainability) tests shall be conducted in the realistic operational conditions. Moreover, NATO Reference Mobility Model in the virtual environment can be helpful to determine the Iguana™ mobility performance by providing valuable feedback for the mobility components design. The NATO Reference Mobility Model (NRMM) is a computer code used to predict the steady-state operating capability of a given vehicle in a prescribed terrain. NRMM determines the

maximum possible speeds versus resisting force relation of the driving elements for vehicle considering its power-train capability. The model then predicts various impediments to vehicle motion as a function of specific terrain factors.(Ref. 7) Unfortunately, The NRMM does not at this time contain a model of the Iguana vehicle.

The input data for the model are segregated into vehicle, terrain, and "scenario" data. The vehicle data describe various physical aspects in engineering terms such as the power train, surface traction elements, sizes, weights, geometry, etc., of the vehicle. The terrain data describe in engineering terms various physical aspects such as soil properties, slope, vegetation, macro- and microgeometry, etc. "Scenario" data consist of generic vehicle and terrain data that are dependent of a specific terrain or vehicle and remain constant for a model execution. Examples of "scenario" data include the driver's reaction time, weather conditions, climatic conditions, vegetation avoid/override strategy, etc. [Ref. 7]

Iguana™ will present an integrated mobility concept by optimizing or surpassing both wheeled and tracked vehicle advantages. The "Mobility Assessment of Marine Corps Wheeled and Tracked Vehicles Using the Stochastic NATO Reference Mobility Model" is a technical report from U.S. Army Corps of Engineers Waterways Experiment Station also emphasizes this urgent mobility requirement for various geographic regions like Kuwait, Philippines and South Korea. The wheeled vehicle's lower levels of vibration and noise which makes them less fatiguing for their occupants can be achieved in Iguana™ armored vehicle family by using the composite armor and hybrid electric drive technologies. When wheeled vehicles use road routes, they consume half the amount of fuel, which reduces the logistics support they require. Iguana™ will also

consume less fuel because of the lightweight composite armor and efficient hybrid electric drive. The amount of terrain, upon which wheeled vehicles, can operate off the road, is less than that of tracked vehicles and decreases significantly with increasing weight. Even if tracked vehicles have superior mobility compared wheeled vehicles on the cross-country drive, they still have serious problems under certain adverse terrain conditions like muddy, rocky, steep and dense vegetation grounds. By comparison the Iguana™ mobility components enable it to operate beyond the current tracked vehicles' operation arena. Iguana™'s higher acceleration capacity, unique trailer design with hydraulic connection mechanism, modular maintenance simplicity, superior obstacle passing ability and all-weather driver visibility equipment consolidate its tactical mobility superiority.

The current dimensions of Iguana™ are extendable proportionally to answer different operational roles, for example, Model 0 was designed for a 2,000 pound payload yet could be scaled up or down to handle larger or smaller payloads. The Iguana's design is open to new modifications and evolving automotive technology continues to expand the range of Iguana™ subsystems available without initiation of major development programs. For example, a new version of the Iguana™ prototype is projected that can disconnect its trailer temporarily. Another important contributor to Iguana™ mobility performance is its use of all of the four possible forward propulsion methods to achieve the desired agility. These are:

1. applying traction
2. using prior gained momentum
3. pumping material backward

4. using hydraulic articulation as a leverage

In May 15 1999, trials of the modified version of first Iguana™ prototype were conducted by the present author. The following figures demonstrate the Iguana™ mobility concept explicitly.

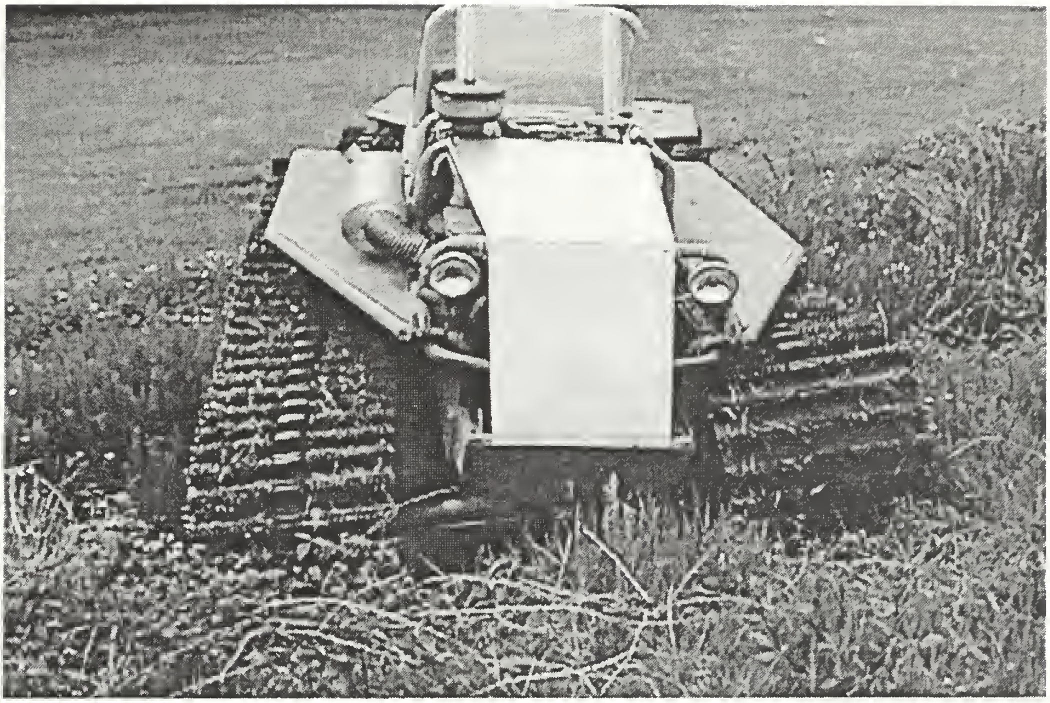


Figure 5. Iguana™ front axle can rotate 15 degree

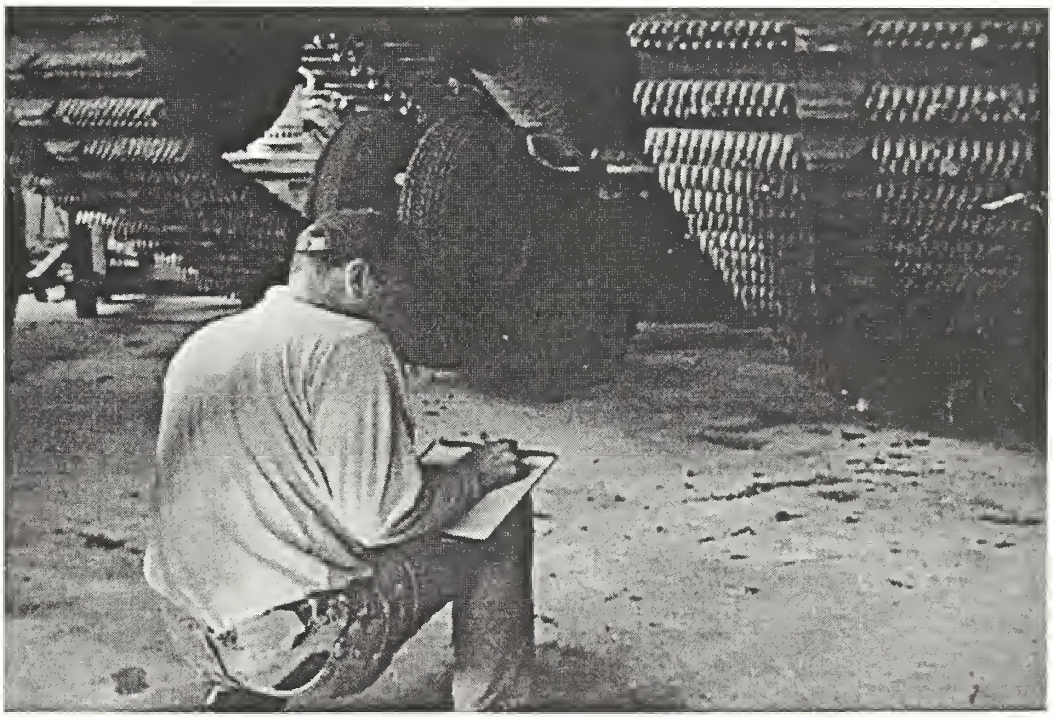


Figure 6. Iguana™ tracks have cone grousers for better traction

Figure 7. Ditch passing with the help of the hydraulic controlled trailer

Figure 8. Ditch passing with the help of the hydraulic controlled trailer

Figure 9. Crossing muddy terrain

Figure 10. Hydraulic connection mechanism for trailer

Figure 11. Hydraulic connection mechanism provides an altitude adjustment ability for obstacle crossing

Figure 12. Hydraulic connection mechanism provides an altitude adjustment ability for obstacle crossing

X. SECOND GENERATION THERMAL IMAGING DEVICE PERFORMANCE TEST

A thermal imaging sensor detects the arrival of IR energy, electronically processes the detected energy, and presents the results for display. The FLIR92 and Acquire computer programs, which are thermal imaging system performance assessment programs, were developed by U.S. Army Night Vision & Electronic Sensors Directorate at Fort Belvoir, Virginia. FLIR92 is used to calculate the modulation transfer function (MTF) and minimum resolvable temperature difference (MRT) curves for first-, second- and third-generation thermal imaging sensors. Acquire is used to generate estimates of the probability of detection, recognition, and identification as a function of target range using the output from FLIR92 as an input. The FLIR92 user specifies system elements (optics, scanner, stabilization, detector, electronic filters, display, etc.) and inputs component parameter values for each element. The computer code calculates the MTF using theoretical and/or semi-empirical MTF functions for each element. It then uses the Ratches model to calculate MRT curves from the MTFs. The Acquire user specifies target characteristics and atmospheric extinction coefficients. The Ratches model is then used in conjunction with Johnson's criteria to calculate the probabilities at various ranges [Ref. 8]. Phenomena incorporated in the code are:

1. Diffraction
2. Atmospheric contrast reduction
3. Sampling effects
4. Motional distortions
5. Stabilization jitter
6. Analog and/or digital electronic filtering

7. Display resolution

8. Visual resolution

9. Visual perception characteristics

10. Detector wavelength response

The specifications of a generic second generation thermal imaging system that were input to FLIR92 program can be found in appendix A as well as the resultant MRT curve results. Basically, the generic thermal imager possessed 8-12 μm spectral response with a 960x4-element detector (4 element time-delay-and-integration) and a 30 cm diameter aperture. The ACQUIRE input files with different atmospheric transmission coefficients found in Appendix A are:

1. For the 2.3 x 2.3 meter standard tank target with 1.25 Kelvin apparent temperature difference

2. For the 0.5 x 0.5 meter standard human target with 16.5 Kelvin apparent temperature difference

The 95% detection and recognition probabilities as a function of atmospheric transmission coefficients and the target detection and recognition ranges are displayed in the Figure 13 and Figure 14 respectively. According to our Iguana™ operational requirement document, the sensor system must have a 95% probability of detection and recognition standard in the 1 dB/km atmospheric attenuation condition (79% transmission per kilometer). It must meet the following target range requirements:

1. For tank, APC, & helicopter type targets the detection range must be 10 km and recognition ranges must be 3.8 km, and

2. For personnel targets, the detection range must be 4.8 km with a 1.24 km recognition range.

Thus, from our analysis of this sensor, its characteristics meet the requirements of the Operational Requirements Document. The figures also show that 95% percent detection and recognition probabilities' ranges for the different atmospheric transmission coefficients can be interpreted operationally as showing the major dependence of IR detection range on weather conditions. In a similar way, calculations can be made for any other proposed thermal imaging system's performance by changing FLIR92 and ACQUIRE input parameters relative to the new sensor system component characteristics. FLIR92 input file parameters in Appendix A were chosen to optimize detection and recognition ranges for a realistic second generation thermal imaging device.

Atmospheric transmission coefficient which is a selectable value in the Figure 13 and 14 can be calculated for specific atmospheric conditions by using LOWTRAN 7, MODTRAN and FASCOD 3 computer models. These computer models have variable sets of regional environmental conditions in order to facilitate global atmospheric attenuation coefficient calculations. LOWTRAN 7 model is designed for low resolution (>20 cm^{-1}) atmospheric transmission & radiance analyses. MODTRAN, which offers ten-fold resolution enhancement and better temperature and pressure dependence than LOWTRAN, is designed for medium resolution (>2 cm^{-1}) atmospheric transmission & radiance analyses. FASCOD3 is designed for laser transmission and/or high-resolution transmittance and radiance (except scattered solar radiance) analyses. It uses line-by-line calculation with contributions from Voigt lineshapes with centers up to 25 cm^{-1} distant for wavelengths.

The apparent temperature difference between target and background in the ACQUIRE input program depends on the actual temperature difference between target

and background, and on the emissivity parameters which are functions of wavelength for both target and background. For example, human skin emissivity value is about 0.98. The global background emissivity values can be obtained from the http://tanalo.larc.nasa.gov:8080/surf_htmls/ems_bb website. Lowtran computer models are also used for apparent temperature difference calculations in detail by using these target and background emissivity values. In the ACQUIRE thermal imaging device performance assessment, the apparent temperature difference between human body temperature (309.5 K) and background (293 K) is taken as 16.5 Kelvin. The 293 K background temperature represents the highest summer night background temperature along Turkish-Iraqi border. The 0.5 meter square exposed area is an appropriate average area for human target when the clothes' effect on the detectable temperature difference and the partial exposed human body area in the combat conditions are taken into consideration. It is assumed that the apparent 1.25 K temperature difference between the tank, APC or helicopter and background is a good average value for total surface area. A characteristic target dimension given by the geometric mean of the target's horizontal and vertical dimensions. The 2.3 meters square exposing area for these targets is acceptable as a worst case sensor orientation toward these targets. 1.25 K for 2.3 m x 2.3 m area is a commonly used standard (tank target signature) in thermal imaging performance analysis.

Johnson's criteria were obtained from a series of psychophysical experiments on perception of image intensifier images when targets were placed at different ranges in a benign terrain context and viewed with an image intensifier by a large number of observers. However, Johnson's criteria are used in slightly modified format in current versions of imaging system performance codes. For 50% probability, the number of

cycles is assumed to be 0.75 for detection and 3.0 for recognition in the ACQUIRE input file. The classification and identification probabilities as a function of range can similarly be calculated by taking the number of cycles of the 50% probability as 1.5 for classification and 6.0 for identification. The 95% probability values needed for comparison with the ORD can be read directly from the Acquire output files.

The blackbody radiation curves in figure 15 shows how the peak radiation wavelength changes with the changing temperature for different blackbody temperatures. So the radiation collected by a sensor that operates at a certain wavelength window will be affected by the emissivity values and actual temperature difference between target and background. The radiation arriving at a sensor after crossing through the atmosphere will consist of the background, reflected sky, and path radiance plus that of the target and will be reduced by atmospheric attenuation. [Figure 16]

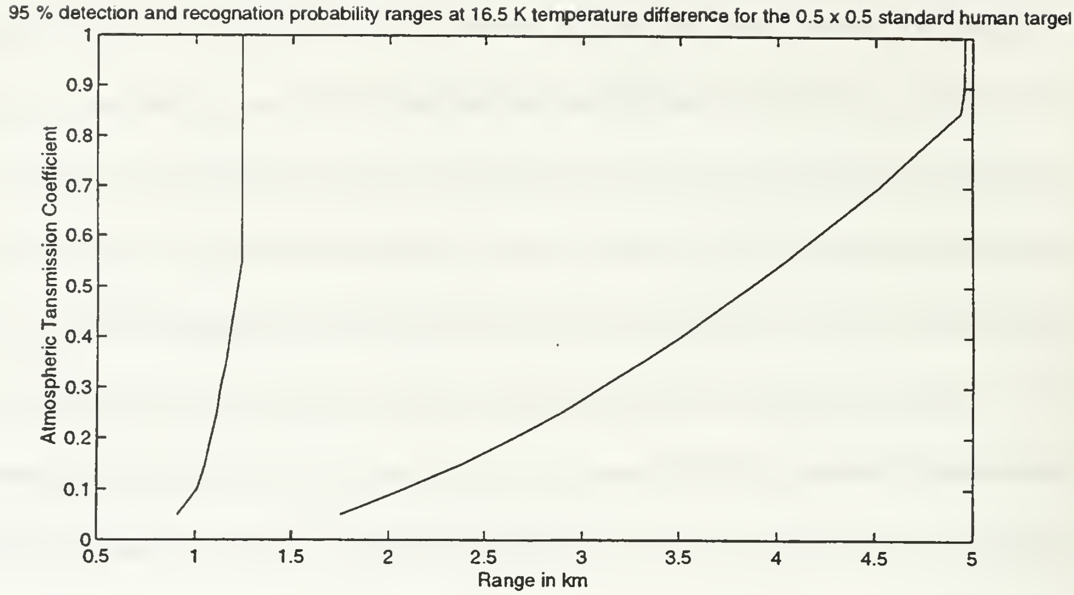


Figure 13. %95 detection and recognition probability ranges at 16.5 K temperature difference for the 0.5 x 0.5 standard human target

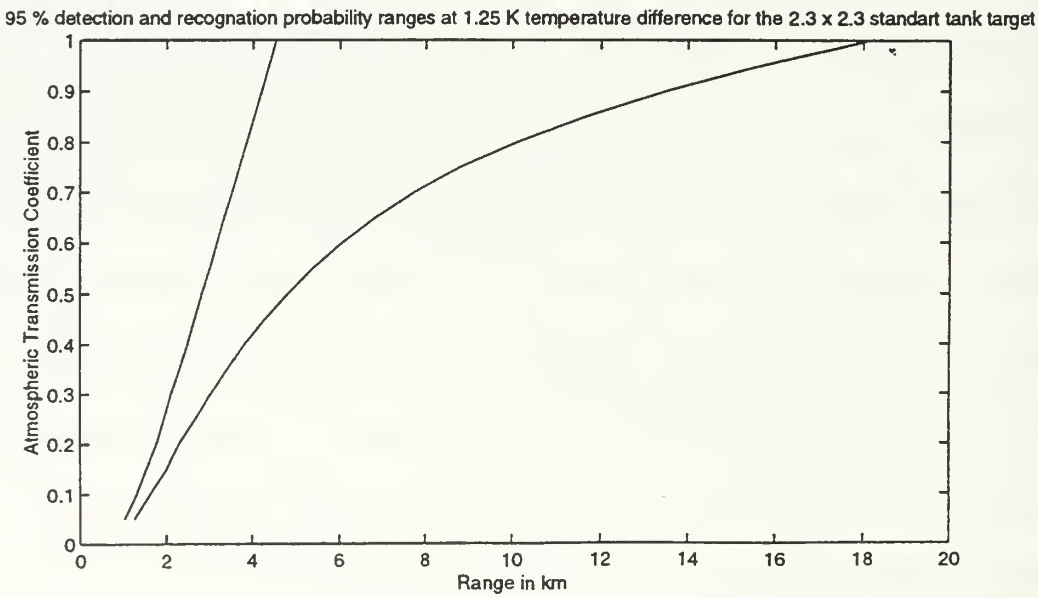


Figure 14. %95 detection and recognition probability ranges at 1.25 K temperature difference for the 2.3 x 2.3 standard tank target

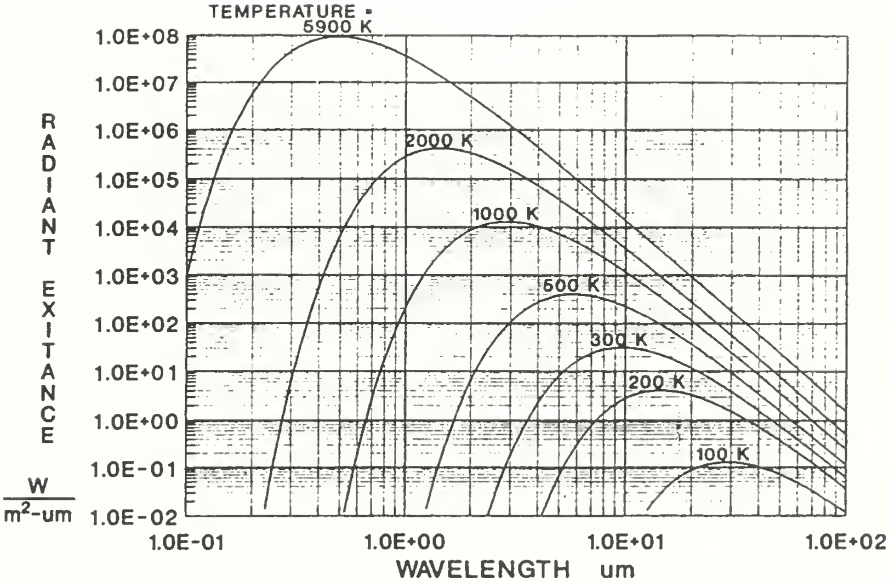


Figure 15. Blackbody Radiation Curves (from Prof. Harney SE 3003 class notes)

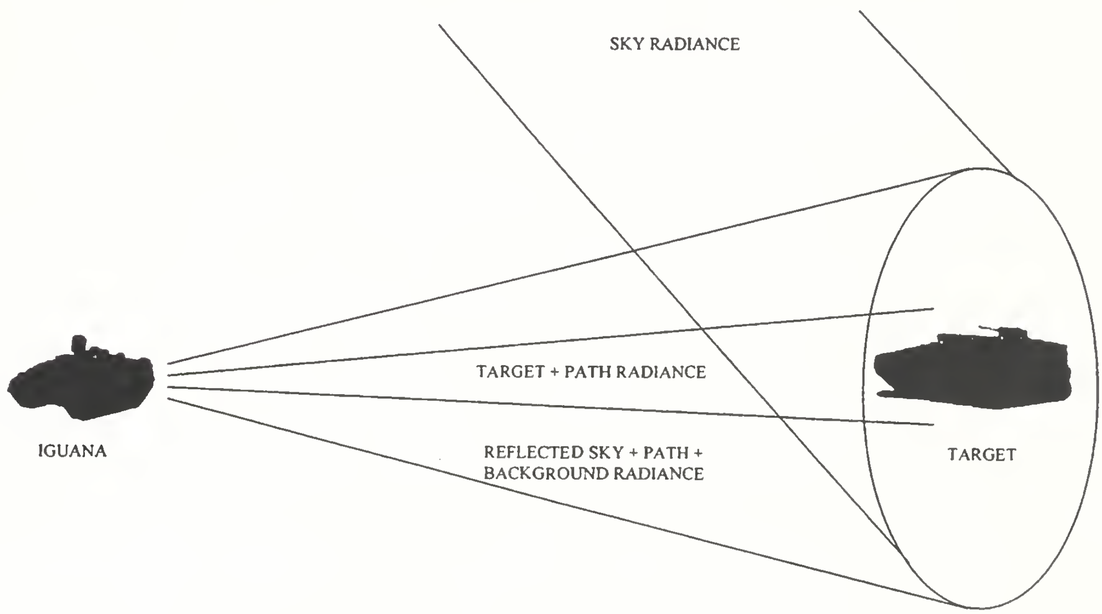


Figure 16. Scenario for detecting a ground target with Iguana^{TM} sensor platform

XI. CONCLUSION

We have derived the operational requirements for a reconnaissance, forward observer and anti-guerrilla version of an armored vehicle. These requirements generally stipulate that common weapon, surveillance, mobility, armor, stealth, digital infrastructure, survivability, and drive system characteristics are desired in the design of these vehicles to meet the tactical requirements of the future combat missions and simplify logistic support. Scenarios and functional flows methods were used to analyze, for each version of the armored vehicle, the operational need. The purpose of this thesis is to conceive of modern armored vehicle created from an integrated combat system and high mobility vehicle exploiting innovative technologies. The composite armor, integrated weapon system, hybrid electric drive, digital C^3I (command, control, communication and intelligence) system, active protection system and integrated sensor technologies all carried on a novel tracked vehicle will offer profound new tactical advantages over armored vehicles currently in service.

A modular and reconfigurable armored vehicle that integrates multiple advanced sensor components including a second–generation thermal imaging sensor, a millimeter wave (MMW) radar with moving target identification (MTI) capability, a daylight television, a multifunction laser (with rangefinding, laser designating, and high–density profiling modes), and acoustic arrays can satisfy current battlefield target acquisition and surveillance requirements. The thermal imaging sensor will operate at high frame rates allowing sniper and mortar detection in addition to the conventional target acquisition functions. Integration of a multifunction multi-wavelength laser system will incorporate ranging, range mapping, laser designation, and target profiling to support

target location, target cueing, target designation, and aided target identification. The acoustic array will provide target cueing and location and will facilitate automated targeting functions. The precise configuration of the armored vehicle's sensor suite will heavily depend on the required detection, recognition and identification probabilities at different ranges in the predetermined atmospheric conditions and on what the user can afford. This sensor platform will provide scout/cavalry, anti-guerrilla and forward observer vehicles with a compact, affordable sensor suite for long–range uncooperative target identification, mortar/sniper fire location, and air defense against low flying targets.

Future armored vehicles will have combined active and passive protection systems. Some components of this system will be the laser and radar warning devices, multispectral smoke rounds, laser jamming devices, IR suppression system and IR decoys rounds. When the active protection system is turned on, it will execute its functions in automatic mode. It will track incoming rounds, ignoring incoming rounds until they are within certain range, then engaging anything approaching at the certain speed interval like 80-800 m/sec. The false targets, such as outgoing rounds, near misses, birds and small projectiles (like splinters or bullets) would be ignored. Active protection system rounds will be fired from the threat-side launcher for the incoming warhead and they will detonate it at a standoff distance that provides survivability.

Hybrid electric drive and composite armor technologies provide low thermal and acoustic signatures for armored vehicles. Composite armor is lighter than conventional armor, so it has a positive effect on the agility of armored vehicle. Hybrid electric drive also enhances the acceleration ability of armored vehicle in addition to its fuel economy

features. Composite armor with the ceramic layers and modular explosive reactive armor is highly penetration resistant while it has reduced spalling spray area and no corrosion problem. The higher insulation feature of composite armor against harsh climate conditions will increase the crew protection and performance. The ability to sneak up on an adversary through the use of lower noise and electromagnetic signatures when using battery power as well as the flexibility of the design configuration are the other advantages of the hybrid electric drive.

The digitization of the Iguana™ will facilitate improvement of C^3I functions for the vehicle commanders by providing timely and secure information dissemination and thereby keep the commanders in the information warfare game. Digitization offers the capability of simultaneous data, voice and imagery communications on multiple nets supporting reliable internal communication. This will contribute to coherent operations with other tactical elements. The global positioning system (GPS) navigation readout, tactical liquid crystal displays (LCD), sensor television displays, very high frequency (VHF) radios, frequency hopping radios and IFF system are some components of the digital infrastructure. Other digitized functions include digital mapping, navigation/ positioning, graphic/alphanumeric messages, tactical situation reports, automatic updating overlays, logistic reports and communication network management.

The armament system of Iguana™ will have a modular design which permit the requirements of the different versions of Iguana™ to be realized without major reengineering. A stabilized 40-mm medium caliber automatic gun that can fire the discarding sabot projectiles in addition to the conventional projectiles will be the main armament for Iguana™ along with a 7.62-mm co-axial machine gun. Its expended cases

will be ejected outside while it has constant velocity feed for smooth and safe operation. Anti-tank guided missile launchers, which can be added to the basic design, will give Iguana™ the extra firepower for the strike force missions.

Figure 17 and Figure 18 show the author's conceptual design for Future Scout and Cavalry System (FSCS). This design has many common subsystem characteristics with Iguana™. So it provides useful clues for the detailed technical design of Iguana™. Appendix B proposes a complete performance test plan, in phases, for an armored vehicle. Such a test plan provides a guide to designers of the expectations of the users and allows for a dialog between designers and users.

Every combat subsystem of Iguana™ presents a new thesis topic for future Studies which would elaborate the design and refine the requirements. The trade-off analyses can be expanded for each subsystem components in order to optimize the integrated engineering design and total system cost. Each subsystem mission timelines must be prepared to assure minimum response time and synchronization among subsystems. The detailed threat analysis for future battle space must be reviewed in the face of advancing technologies. The schematic block diagrams of the components can be conceived by extracting from the functional flow description provided here the design requirements for those components and from the system architecture. These schematic descriptions are a precursor to the detail engineering design diagrams. To achieve the sought after higher system performance, the performance of the crew and other system components must be understood. For example, crew training in the use of the IR system is necessary to realize the detection and identification criteria specified by Johnson.

Thus, the integration study must deal with training issues and what is required to achieve the needed level of performance.

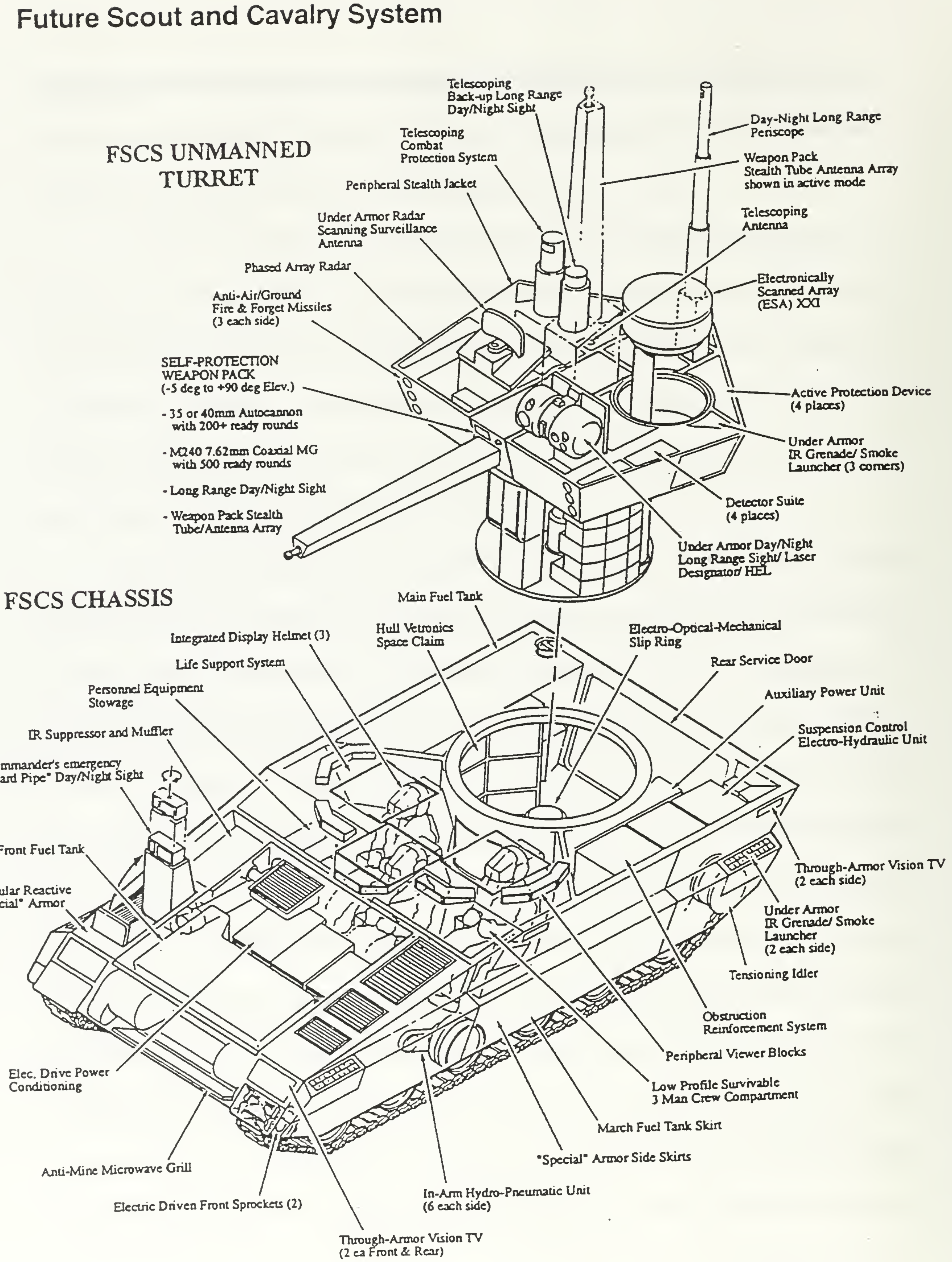
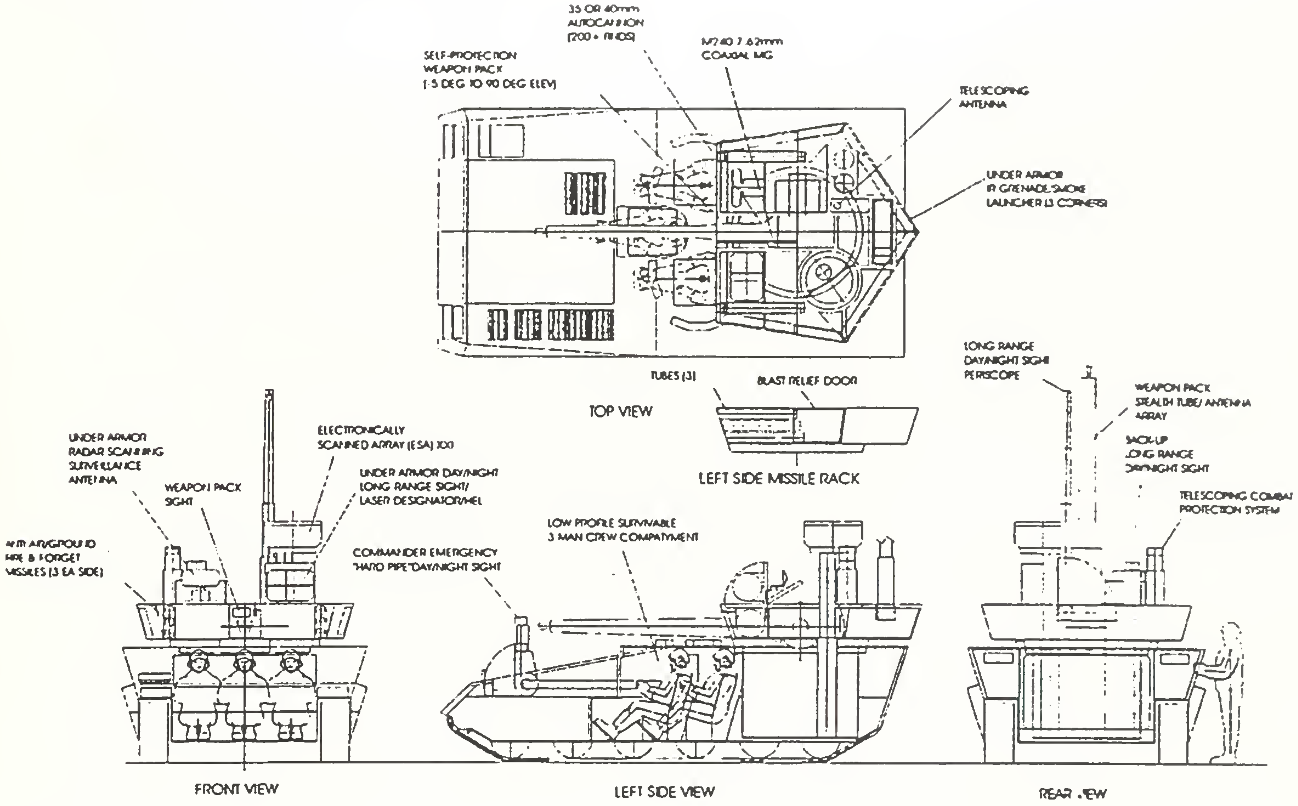


Figure 17. The first drawing of an independent FSCS conceptual design (from ARMOR magazine (January/February 1999))

FSCS Concept Vehicle Details



FCS Concept Vehicle (Overall View)

(Sensing Devices Under Armor)

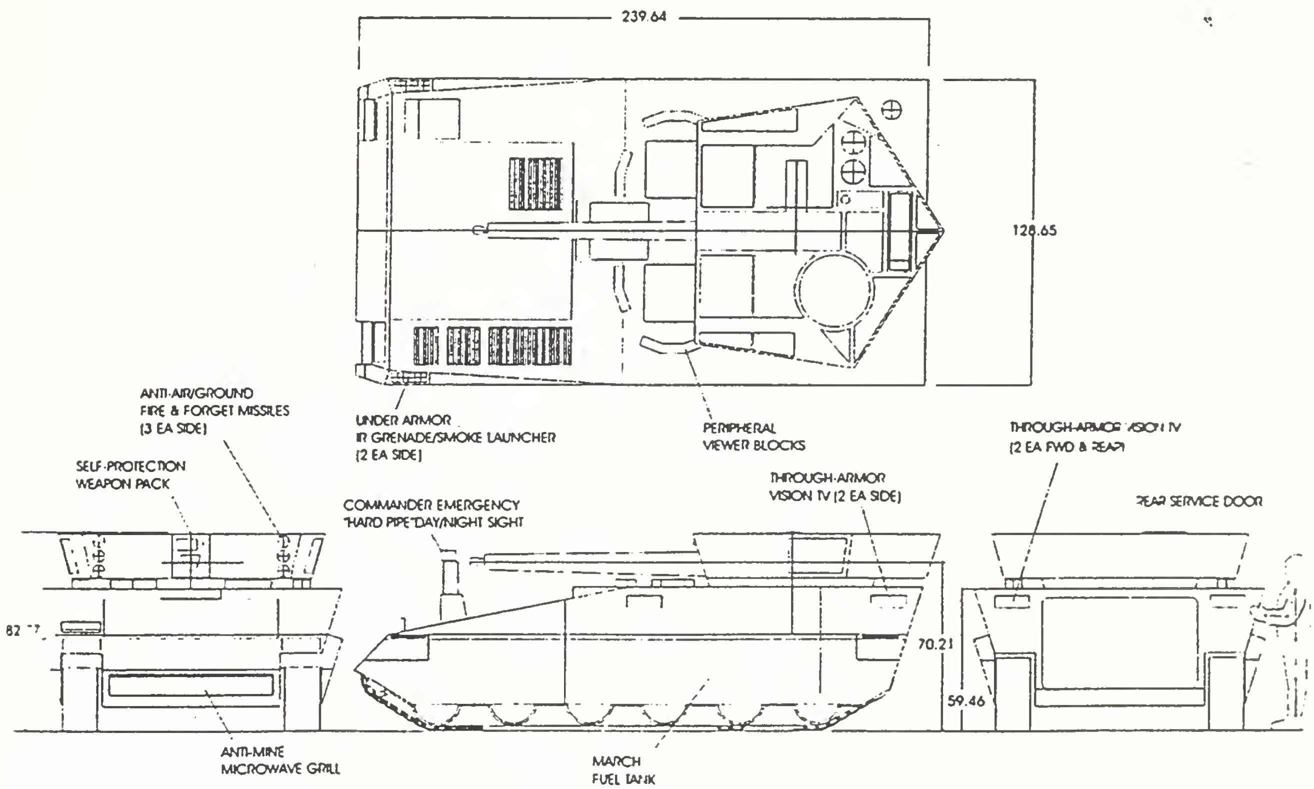


Figure 18. The second drawing of an independent FSCS conceptual design (from ARMOR magazine (January/February 1999))

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2. David Ethel, "Armored Anti-Guerrilla Combat in South Lebanon" Armor Magazine, pp. 26-29, July-August 1997 issue

3. Hugh Dickens, The US/UK Recce Route, Defence Systems Daily, February 10, 1999

4. The operational requirements document of the future armored resupply vehicle, http://sill-www.armymil/tngcmd/tsmcannon/ordhtmls/FARV_ORD.HTM

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6. Paul Horback, "Problems Persist, But Continuous Band Track Shows Promise in Light Armor Applications", Armor Magazine, pp. 21-22, January-February 1999 issue

7. John G. Green and Randolph A. Jones, "Mobility Assessment of Marine Corps Wheeled and Tracked Vehicles Using the Stochastic NATO Reference Mobility Model" technical report, U.S. Army Corps of Engineers Waterways Experiment Station, January 1997

8. R.C. Harney, Flir92 and Acquire Section, SE 3003 class notes, Winter 1999

APPENDIX A. FLIR92 AND ACQUIRE INPUT/OUTPUT FILES

A.FLIR92 INPUT FILE:

```
gen2: sample data file for 2nd generation FLIR
        >spectral
            spectral_cut_on                8.0       microns
            spectral_cut_off              12.0       microns
            diffraction_wavelength         0.0       microns
        >optics_1
            f_number                       2.0       --
            eff_focal_length              60.0       cm
            eff_aperture_diameter          0.0       cm
            optics_blur_spot               0.01      mrad
            average_optical_trans          0.7       --
        >optics_2
            HFOV:WFOV_aspect_ratio         1.33      --
            magnification                  0.0       --
            frame_rate                    30.0       Hz
            fields_per_frame               1.0       Hz
        >detector
            horz_dimension_(active)       20.0       microns
            vert_dimension_(active)       20.0       microns
            peak_D_star                   10.0e10    cm-sqrt(Hz)/W
            integration_time              10.0       microsec
            1/f_knee_frequency           100.0       Hz
        >fpa_parallel
            #_detectors_in_TDI             4.0       --
            #_vert_detectors             960.0       --
            #_samples_per_HIFOV            2.0       --
            #_samples_per_VIFOV            2.0       --
            3dB_response_frequency       500000.0    Hz
            scan_efficiency                0.75      --
        >electronics
            high_pass_3db_cuton            1.0       Hz
            high_pass_filter_order         1.0       --
            low_pass_3db_cutoff       100000.0       Hz
            low_pass_filter_order          1.0       --
            boost_amplitude                0.0       --
            boost_frequency                0.0       Hz
            sample_and_hold                HORZ      NO_HORZ_VERT
        >display
            display_brightness            10.0       milli-Lamberts
            display_height                15.24      cm
            display_viewing_distance      30.0       cm
        >crt_display
            #_active_lines_on_CRT        480.0       --
            horz_crt_spot_sigma            0.0       mrad
            vert_crt_spot_sigma            0.0       mrad
        >eye
            threshold_SNR                  2.5       --
            eye_integration_time           0.1       sec
            MTF                            EXP       EXP_or_NL
        >3d_noise_measurements
            sigma_TVH                      0.10      --
            sigma_TV                       0.05      --
```

```
    sigma_TH                        0.01      --
    sigma_VH                        0.0       --
    sigma_V                         0.05      --
    sigma_H                         0.0       --
>random_image_motion
    horz_rms_motion_amplitude       0.02      mrad
    vert_rms_motion_amplitude       0.02      mrad
>spectral_detectivity
    #_points: 8   microns____detectivity
                     7.5        0.55
                     8.0        0.6
                     9.0        0.7
                    10.0        0.8
                    11.0        0.9
                    11.5        0.95
                    12.0        1.0
                    12.5        0.1
>end
```

B. FLIR92 OUTPUT FILE

```
U.S. Army CECOM NVESD FLIR92        Thu Mar 11 08:05:12 1999

output file: gen2.1     short listing

data file: gen2
command line arguments:  -d gen2 -o gen2 -p MRT

begin data file listing . . .
gen2: sample data file for 2nd generation FLIR
        >spectral
            spectral_cut_on                   8.0       microns
            spectral_cut_off                 12.0       microns
            diffraction_wavelength            0.0       microns
        >optics_1
            f_number                          2.0       --
            eff_focal_length                 60.0       cm
            eff_aperture_diameter             0.0       cm
            optics_blur_spot                  0.01      mrad
            average_optical_trans             0.7       --
        >optics_2
            HFOV:WFOV_aspect_ratio            1.33      --
            magnification                     0.0       --
            frame_rate                       30.0       Hz
            fields_per_frame                  1.0       Hz
        >detector
            horz_dimension_(active)          20.0       microns
            vert_dimension_(active)          20.0       microns
            peak_D_star                      10.0e10    cm-sqrt(Hz)/W
            integration_time                 10.0       microsec
            1/f_knee_frequency              100.0       Hz
        >fpa_parallel
            #_detectors_in_TDI                4.0       --
            #_vert_detectors                960.0       --
            #_samples_per_HIFOV               2.0       --
            #_samples_per_VIFOV               2.0       --
            3dB_response_frequency          500000.0    Hz
            scan_efficiency                   0.75      --
        >electronics
            high_pass_3db_cuton               1.0       Hz
            high_pass_filter_order            1.0       --
            low_pass_3db_cutoff          100000.0       Hz
            low_pass_filter_order             1.0       --
            boost_amplitude                   0.0       --
            boost_frequency                   0.0       Hz
            sample_and_hold                   HORZ      NO_HORZ_VERT
        >display
            display_brightness               10.0       milli-Lamberts
            display_height                   15.24      cm
            display_viewing_distance         30.0       cm
        >crt_display
            #_active_lines_on_CRT           480.0       --
            horz_crt_spot_sigma               0.0       mrad
            vert_crt_spot_sigma               0.0       mrad
        >eye
            threshold_SNR                     2.5       --
```

```
        eye_integration_time            0.1        sec
        MTF                             EXP        EXP_or_NL
    >3d_noise_measurements
        sigma_TVH                       0.10       --
        sigma_TV                        0.05       --
        sigma_TH                        0.01       --
        sigma_VH                        0.0        --
        sigma_V                         0.05       --
        sigma_H                         0.0        --
    >random_image_motion
        horz_rms_motion_amplitude       0.02       mrad
        vert_rms_motion_amplitude       0.02       mrad
    >spectral_detectivity
        #_points: 8   microns____detectivity
                        7.5        0.55
                        8.0        0.6
                        9.0        0.7
                       10.0        0.8
                       11.0        0.9
                       11.5        0.95
                       12.0        1.0
                       12.5        0.1
    >end
end data file listing . . .

MESSAGES
  diagnostic(): Using measured 3D noise components.
  diagnostic(): Diffraction wavelength set to spectral band midpoint.
  diagnostic(): Fields-of-view calculated by model.
  h_tpf_mtf(): Temporal postfilter did not converge to 0.


CALCULATED SYSTEM PARAMETERS
      field-of-view:      1.219h x  0.917v degrees
                          21.28h x  16.00v mrad
      magnification:                31.093
      optics blur spot:             48.800 microns (diffraction-limited)
                                     0.081 mrad

      detector IFOV:      0.033h x  0.033v mrad

      scan velocity:                851.16 mrad/second
      dwell time:                3.916e-005 seconds

TEMPERATURE DEPENDENCE
      parameter   NETD @ 300 K      NETD @   0 K      noise bandwidth
      ---------   ------------      ------------      ---------------
      white NETD  0.052 deg C 0.000 deg C 2.006e+004 Hz
      classical NETD    0.054 deg C 0.000 deg C 2.147e+004 Hz
      sigma_TVH NETD    0.100 deg C 0.000 deg C 4.285e+004 Hz

      sigma_TV NETD     0.050 deg C 0.000 deg C
      sigma_TH NETD     0.010 deg C 0.000 deg C
      sigma_V NETD      0.050 deg C 0.000 deg C

      Planck integral   1.978e-004  0.000e+000  W/(cm*cm*K)
      . . . w/D-star    1.555e+007  0.000e+000  sqrt(Hz)/(cm*K)
```

TOTAL HORIZONTAL MTFs

cy/mr	H_SYS	H_PRE	H_TPF	H_SPF
0.000	1.000	1.000	1.000	1.000
1.500	0.856	0.912	1.000	0.939
3.000	0.678	0.785	1.000	0.864
4.500	0.496	0.637	0.999	0.778
6.000	0.335	0.488	0.999	0.687
7.500	0.209	0.352	0.998	0.594
9.000	0.120	0.238	0.997	0.503
10.500	0.063	0.152	0.996	0.418
12.000	0.031	0.091	0.995	0.340
13.500	0.014	0.051	0.993	0.271
15.000	0.006	0.026	0.992	0.211
16.500	0.002	0.013	0.990	0.161
18.000	0.001	0.006	0.988	0.121
19.500	0.000	0.002	0.986	0.088
21.000	0.000	0.001	0.984	0.063
22.500	0.000	0.000	0.981	0.045
24.000	0.000	0.000	0.979	0.031
25.500	0.000	0.000	0.976	0.021
27.000	0.000	0.000	0.974	0.014
28.500	0.000	0.000	0.971	0.009
30.000	0.000	0.000	0.968	0.000

TOTAL VERTICAL MTFs

cy/mr	H_SYS	H_PRE	H_SPF
0.000	1.000	1.000	1.000
1.500	0.857	0.912	0.940
3.000	0.681	0.786	0.867
4.500	0.502	0.639	0.785
6.000	0.342	0.490	0.698
7.500	0.216	0.354	0.610
9.000	0.126	0.241	0.523
10.500	0.068	0.154	0.440
12.000	0.033	0.092	0.363
13.500	0.015	0.052	0.295
15.000	0.006	0.027	0.234
16.500	0.002	0.013	0.183
18.000	0.001	0.006	0.141
19.500	0.000	0.002	0.106
21.000	0.000	0.001	0.078
22.500	0.000	0.000	0.057
24.000	0.000	0.000	0.041
25.500	0.000	0.000	0.028
27.000	0.000	0.000	0.019
28.500	0.000	0.000	0.013
30.000	0.000	0.000	0.009

PREFILTER VALUES AT NYQUIST

horz H_PRE(30.00) = 0.000   vert H_PRE(30.00) = 0.000

SAMPLING RATES

horizontal	60.00	samples/mr
vertical	60.00	samples/mr
effective	60.00	samples/mr

SENSOR LIMITING FREQUENCIES

	spatial	Nyquist
horizontal	30.00	30.00
vertical	30.00	30.00
effective	30.00	30.00

MRTD 3D NOISE CORRECTION (AVERAGE)

	300 K	0 K
horizontal	1.125	0.000
vertical	5.290	0.000

MRTD AT 300 K BACKGROUND TEMPERATURE

	cy/mr	horz		cy/mr	vert	cy/mr	2D
0.05	1.500	0.005	0.05	1.500	0.044	3.219	0.044
0.10	3.000	0.010	0.10	3.000	0.074	4.193	0.058
0.15	4.500	0.017	0.15	4.500	0.118	5.093	0.078
0.20	6.000	0.030	0.20	6.000	0.191	6.025	0.103
0.25	7.500	0.056	0.25	7.500	0.323	6.884	0.137
0.30	9.000	0.107	0.30	9.000	0.581	7.701	0.183
0.35	10.500	0.221	0.35	10.500	1.118	8.455	0.243
0.40	12.000	0.487	0.40	12.000	2.315	9.178	0.324
0.45	13.500	1.164	0.45	13.500	5.190	9.844	0.431
0.50	15.000	3.023	0.50	15.000	12.659	10.493	0.574
0.55	16.500	8.583	0.55	16.500	33.776	11.088	0.763
0.60	18.000	26.847	0.60	18.000	99.254	11.678	1.016
0.65	19.500	93.373	0.65	19.500	99.999	12.231	1.352
0.70	21.000	99.999	0.70	21.000	99.999	12.761	1.800
0.75	22.500	1.122	0.75	22.500	99.999	13.286	2.395
0.80	24.000	5.966	0.80	24.000	99.999	13.779	3.187
0.85	25.500	39.983	0.85	25.500	99.999	14.257	4.242
0.90	27.000	99.999	0.90	27.000	99.999	14.727	5.646
0.95	28.500	99.999	0.95	28.500	99.999	15.176	7.514
1.00	30.000	99.999	1.00	30.000	99.999	15.617	10.000

FLIR92. . . gen2.1: end of listing

C. ACQUIRE INPUT FILE

```
gen2_t0.acq: ACQUIRE data file: FLIR92 v1: Tue Feb 02 10:34:43 1993
source data file: gen2          background temperature: 293 K

Target Length                  Target Height                    Delta T
0.5000                         0.5000                           16.5000

Atmospheric Transmittance      Smoke Mass Extinction            Smoke CL
0.5000                         0.0000                           0.0000

 # MRTD Data Points            Cycle Criterion #1               Cycle
Criterion #2
 20.0                          0.7500                           3.0000

 WFOV/NFOV Ratio    WFOV:      Cycle Criterion #1               Cycle
Criterion #2
 0.0000                        0.0000                           0.0000

 1-D Performance Flag          Search Time                      Maximum
Range
 0.0000                        0.0000                           30.0000
```

cycles/mrad	2D MRTD	HORZ MRTD	VERT MRTD
3.219	0.044		
4.193	0.058		
5.093	0.078		
6.025	0.103		
6.884	0.137		
7.701	0.183		
8.455	0.243		
9.178	0.324		
9.844	0.431		
10.493	0.574		
11.088	0.763		
11.678	1.016		
12.231	1.352		
12.761	1.800		
13.286	2.395		
13.779	3.187		
14.257	4.242		
14.727	5.646		
15.176	7.514		
15.617	10.000		

D. ACQUIRE OUTPUT FILE

```
********************************************************************************
VISTA/ACQUIRE

          U.S. Army CECOM Center for Night Vision and Electro-Optics
                     E-O Sensor Target Acquisition Model

                       ACQUIRE version 0, 31 May 1990

Date: 06/01/1999
Time: 2052 hours
********************************************************************************

  gen2_t0.acq: ACQUIRE data file: FLIR92 v1: Tue Feb 02 10:34:43 1993
  source data file: gen2            background temperature: 293 K

 Input Data

  Target Length (meters)           .50
  Target Height (meters)           .50
  Target Root-Area (meters)        .50
  Target Delta T (deg C)         16.50
  Atmospheric Transmission (km-1)  .50
  Cycle Criteria (N50)             .75 -N50 #1   3.00 -N50 #2

 Subjective Resolution for NFOV

  Freq       Xmrt         Ymrt         2D mrt

 3.219     .419E+01     .580E-01     .440E-01
 5.093     .603E+01     .103E+00     .780E-01
 6.884     .770E+01     .183E+00     .137E+00
 8.455     .918E+01     .324E+00     .243E+00
 9.844     .105E+02     .574E+00     .431E+00
11.088     .117E+02     .102E+01     .763E+00
12.231     .128E+02     .180E+01     .135E+01
13.286     .138E+02     .319E+01     .239E+01
14.257     .147E+02     .565E+01     .424E+01
15.176     .156E+02     .100E+02     .751E+01
15.226     .100E+11     .100E+11     .100E+11
```

Field Performance based on both directions

RANGE (km)	P(#1)	P(#2)	PROBABILITY	RANGE for TASK #1	RANGE for TASK #2
			.95	3.87	1.22
			.90	4.29	1.40
			.85	4.58	1.55
			.80	4.82	1.67
			.75	5.03	1.78
			.70	5.21	1.89
			.65	5.39	1.99
			.60	5.55	2.09
			.55	5.71	2.20
			.50	5.87	2.31
			.45	6.04	2.43
			.40	6.20	2.56
			.35	6.37	2.70
			.30	6.56	2.86
			.25	6.75	3.05
			.20	6.98	3.28
			.15	7.23	3.58
			.10	7.55	4.01

APPENDIX B. IGUANA™ TEST PLAN

The following field performance tests will be executed in a wide spectrum of terrain, weather and visibility conditions in addition to the virtual performance test models.

A. Mobility Test :

The mobility specifications that explain in the 4A section of the operation requirement document (ORD) will be performed in the different ground characteristics with the recovery exercise of Iguana™.

B. Surveillance Test :

A possible combination of radar, acoustic, thermal night vision/image intensifier and day sights will be checked in order to satisfy the ORD detection and recognition requirements.

C. Command, Control, Communication and Intelligence Functions Test :

Radios, navigation devices, tactical displays, global positioning system (GPS), North seeker, interface devices, video recording, secure data/voice/picture transfer, electronic countermeasures will be checked.

D. Survivability Test :

Mine blast test, NBC test, armor test against kinetic energy and shaped charge rounds, fire suppression test will be executed. The warning systems (such as laser warning device or chemical agent detector), active protection measures (such as laser jammer) and identification of friend or foe (IFF) will be checked.

E. Weapons Test :

Firepower (missile, automatic canon, automatic grenade launcher, coaxial machine gun and turret machine gun, multi-spectral smoke mortar, 60-mm on-board mortar) will be evaluated at various ranges in live fire. The turret specifications, range finding, stabilization system and fire control system performance will be checked.

F. Low Detection Signature Test :

Radar, IR, acoustic, visible, seismic signatures will be checked in various backgrounds under different weather conditions.

G. RAM (Reliability, Availability, Maintainability) Tests :

The long-term service trials in military units for a 6 months period will exhibit the actual problems of the end users and provide a valuable feedback for designers. Engine change in terrain conditions, periodic unit level maintenance and track repair will be main inspection areas.

H. Transportation Test :

Air, sea, rail, trailer transportation types will be tried with airdrop operation.

I. Force-On-Force Scenarios Test :

We can realistically evaluate the demanded characteristics of Iguana™ in the force-on-force field exercises according to the related scenarios by using laser engagement systems.

I. Comparison Test :

The above performance tests will be executed with the current similar combat vehicles in the same conditions.

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